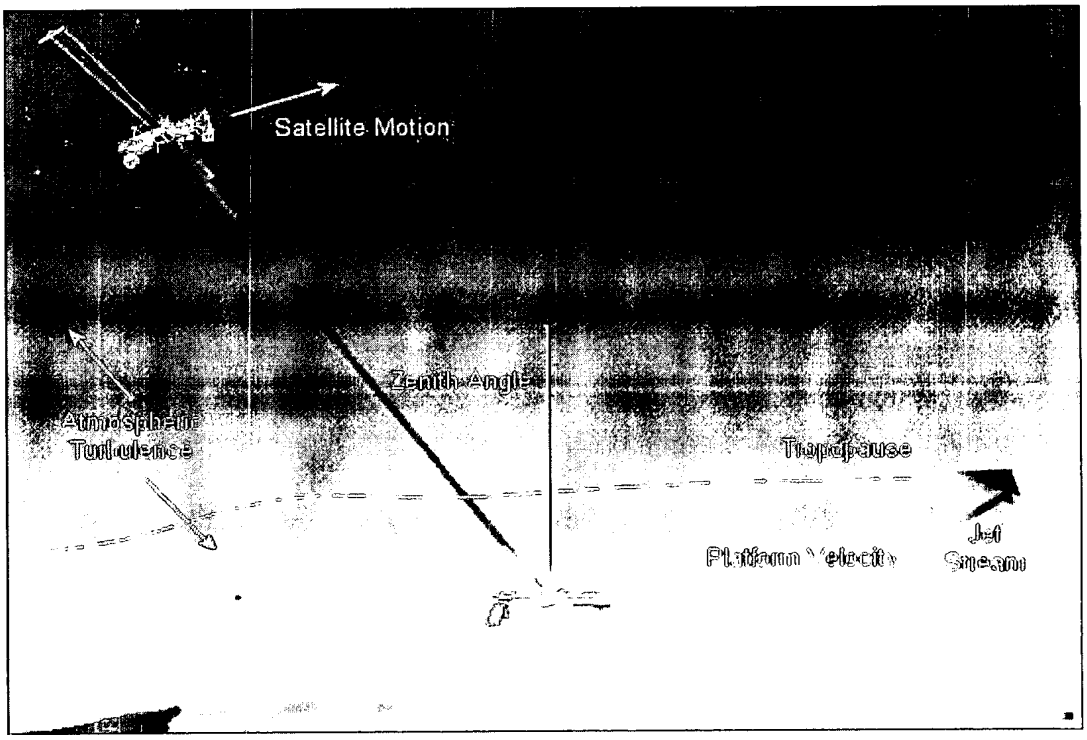
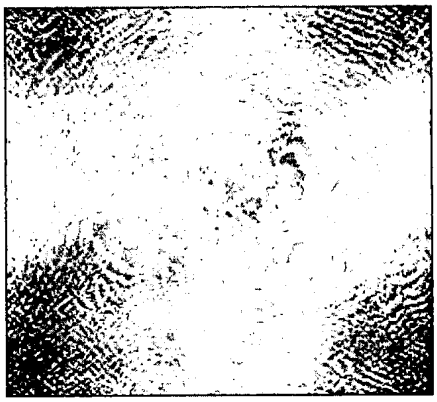
OIPE IAP70
JUL 16 2007
PATENT & TRADEMARK OFFICE



Platform Parameters

FIG. 1A

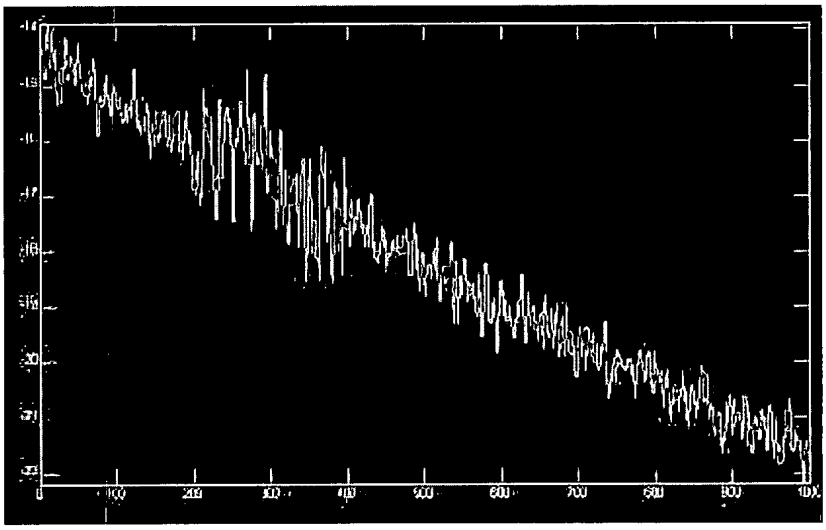


Phase Map Through Turbulence

FIG. 1B

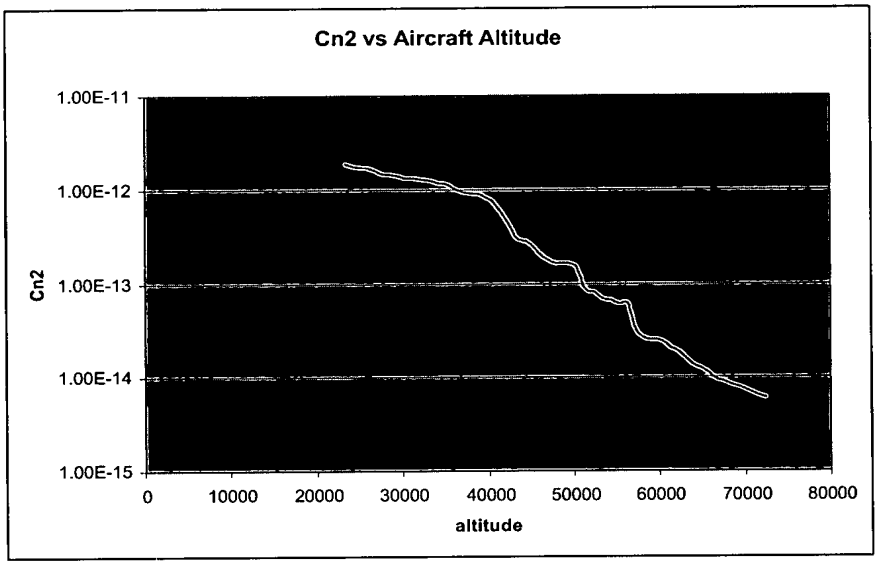
Time Sequence of Beam Distribution at Satellite
(bar represents 10m at 1000km)

FIG. 1C



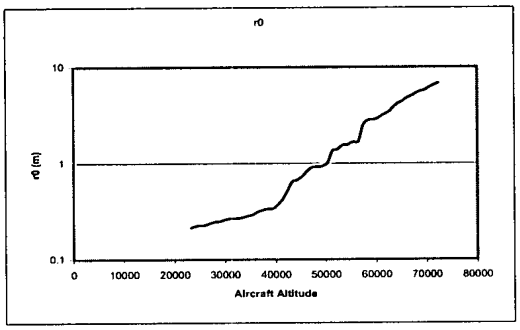
Simulated C_n^2 profile

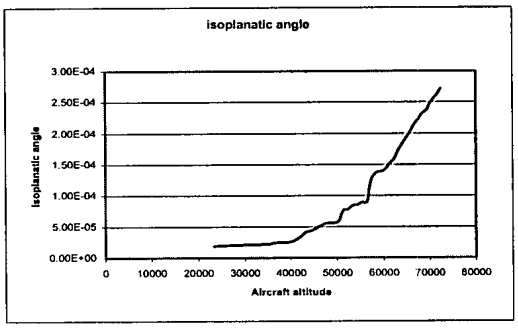
FIG. 1D



Integrated C_n^2 versus aircraft altitude in feet

FIG. 1E

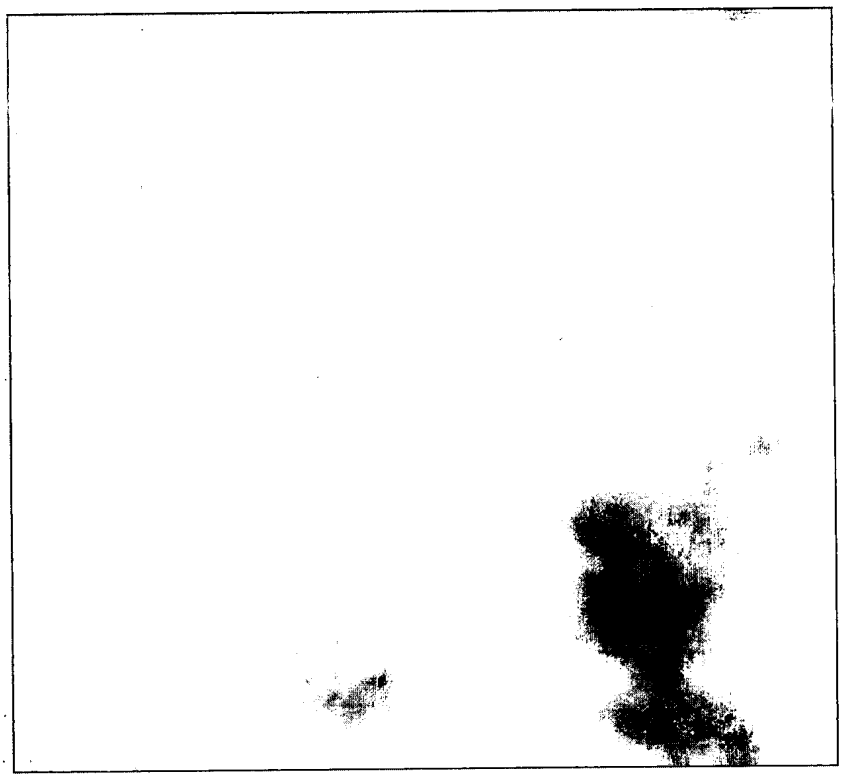




Atmospheric coherence parameters versus aircraft altitude

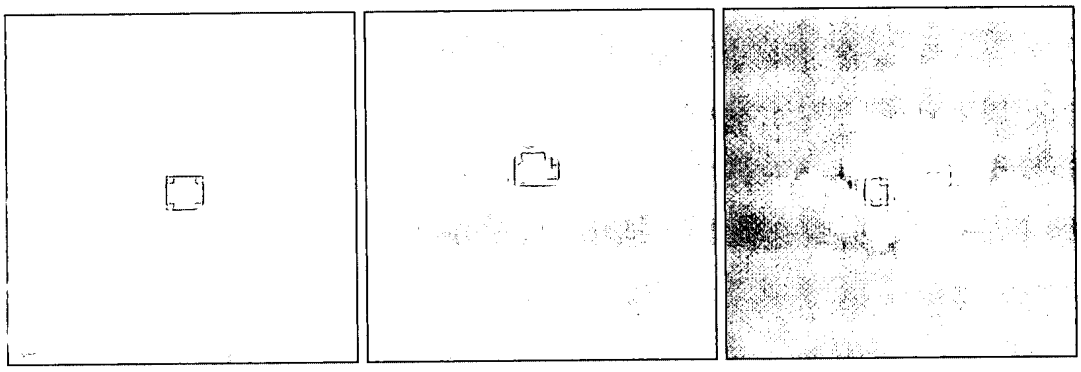
FIG. 1F1

FIG. 1F2



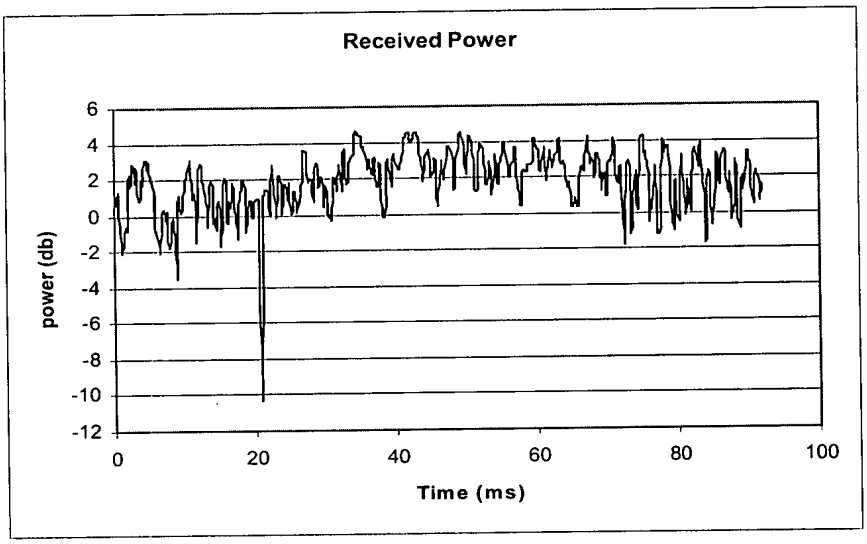
Simulated turbulence induced phase error

FIG. 1G



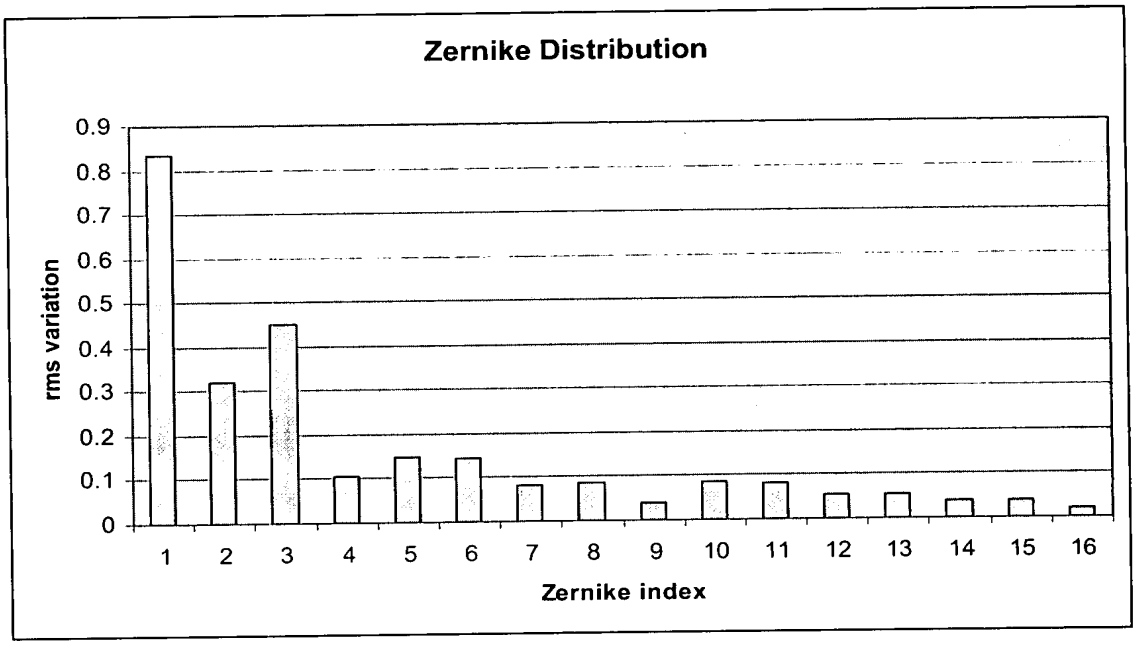
Diffraction limited beam profile (left) and typical beam profiles at satellite

FIG. 1H



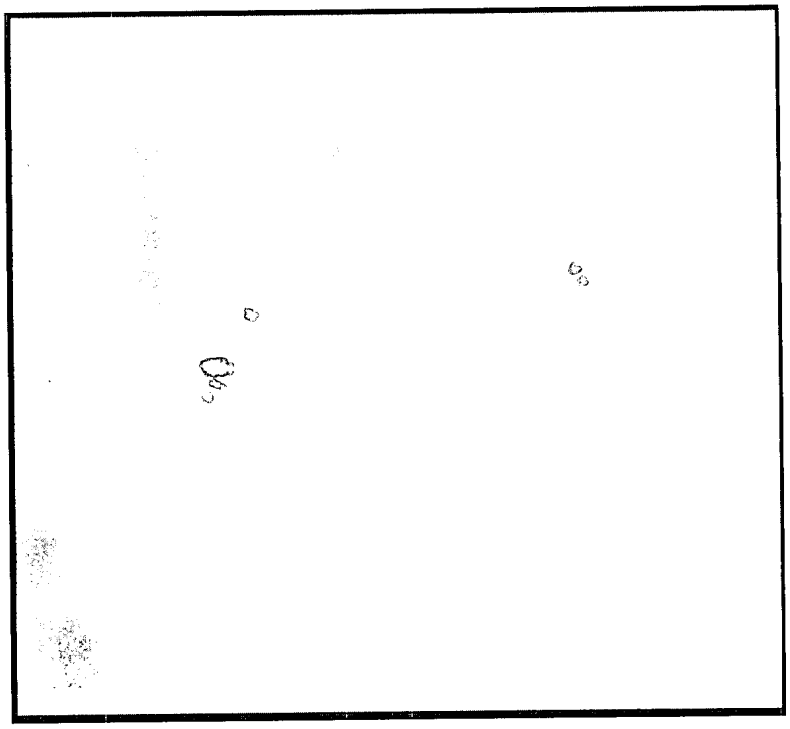
Time Series of Received Power

FIG. 1I



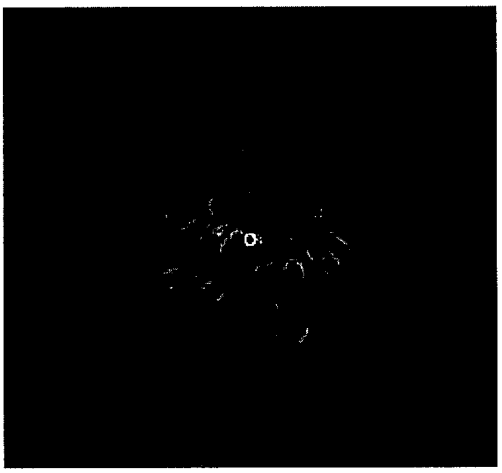
Temporal Variation in Lowest 15 Zernike terms

FIG. 1J



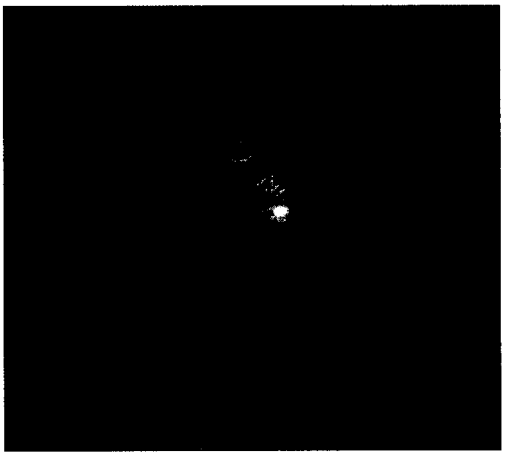
Intensity distribution at receiver aperture

FIG. 1K



Spot during a deep fade event

FIG. 1M



Typical calculated spot at detector plane

FIG. 1L

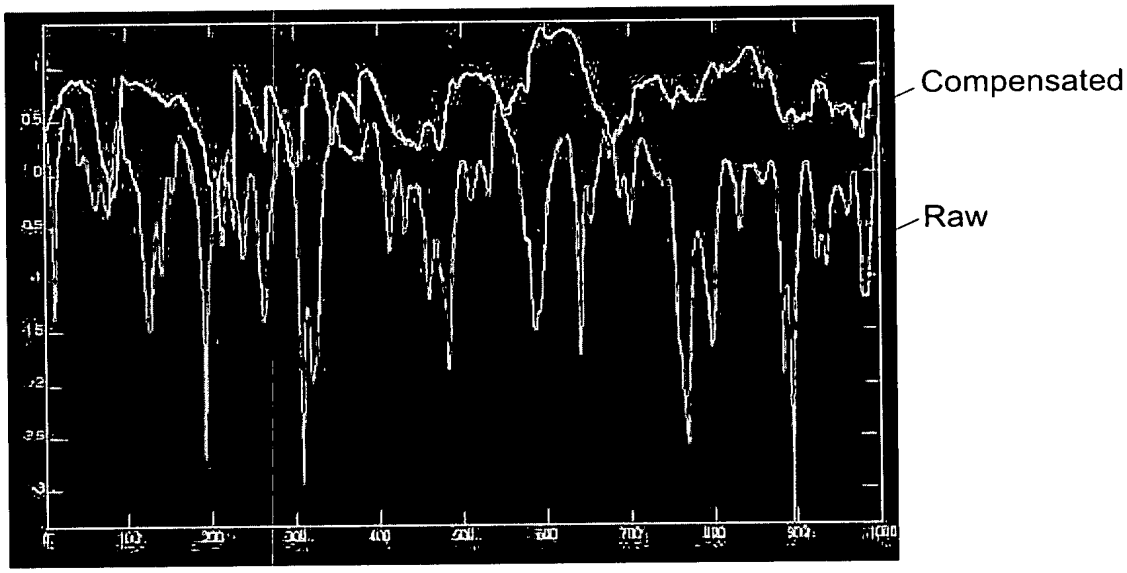


FIG. 1N

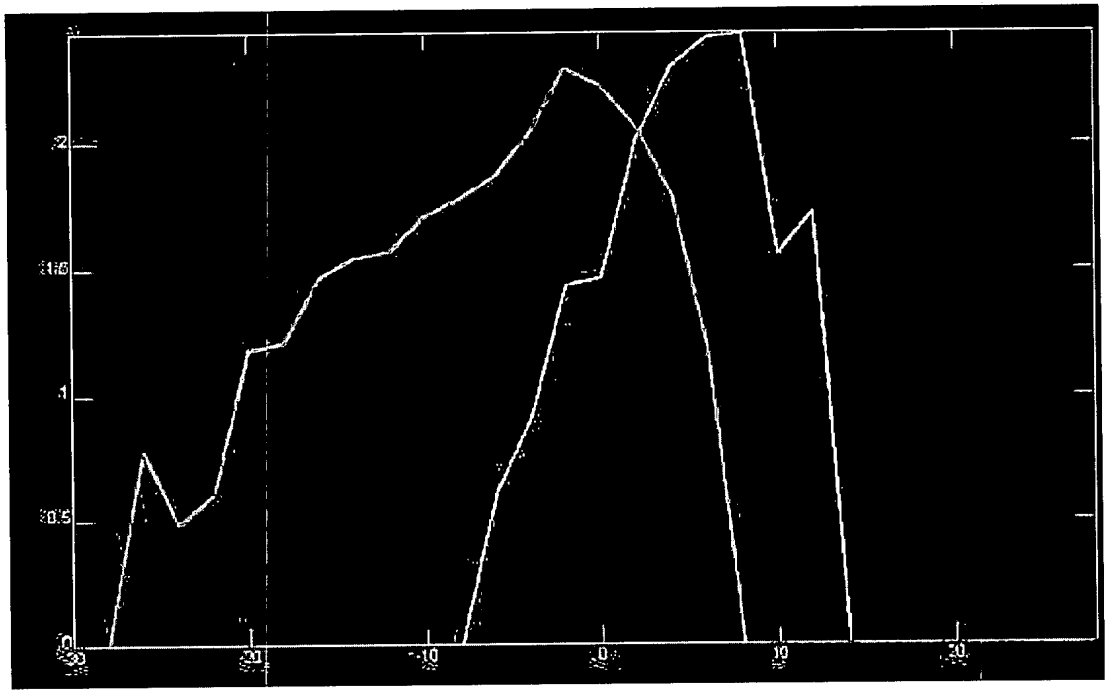
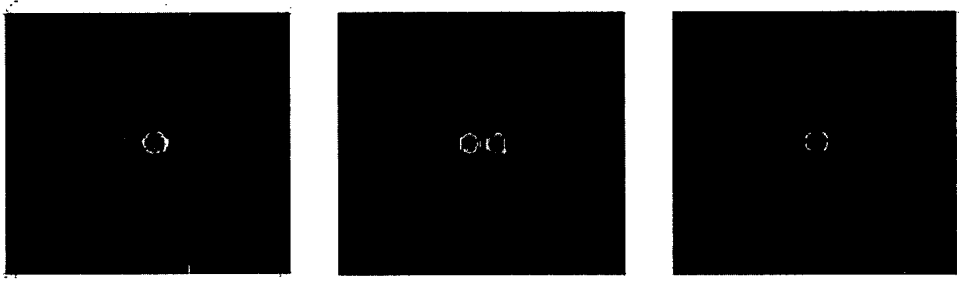
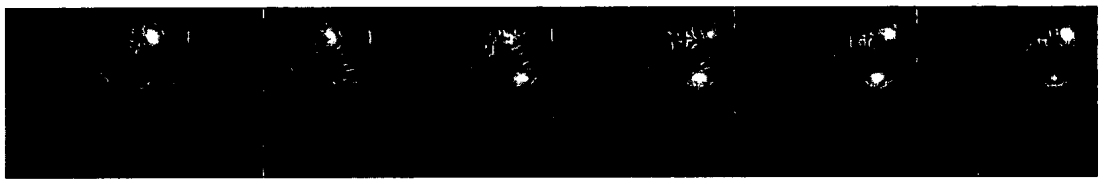


FIG. 1O



Blur spots formed by aperture with 0.2, 0.5, and 1.0 wave phase steps

FIG. 1P



Modulation of a speckle pattern by a phase step

FIG. 1Q

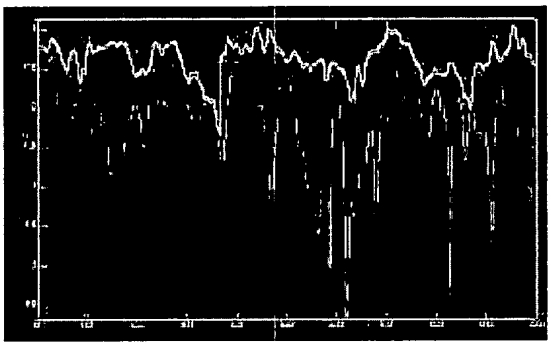


FIG. 1R1

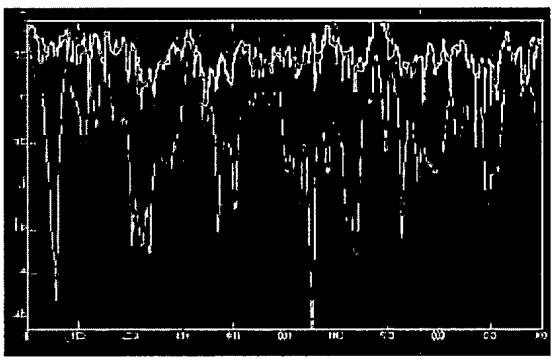
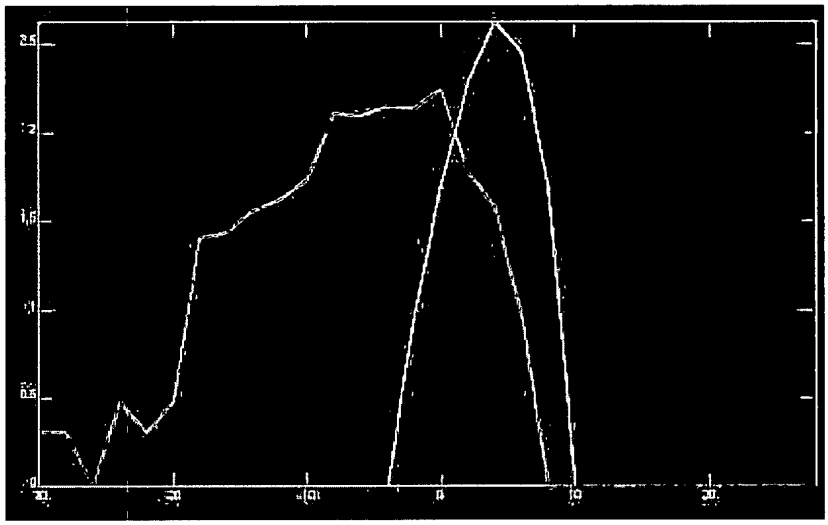


FIG. 1R2

Log intensity vs. iteration number.
Left, 2X2 phase modulator; right, 4X4 phase modulator.



PDF for the data in Fig. 9K2

FIG. 1S

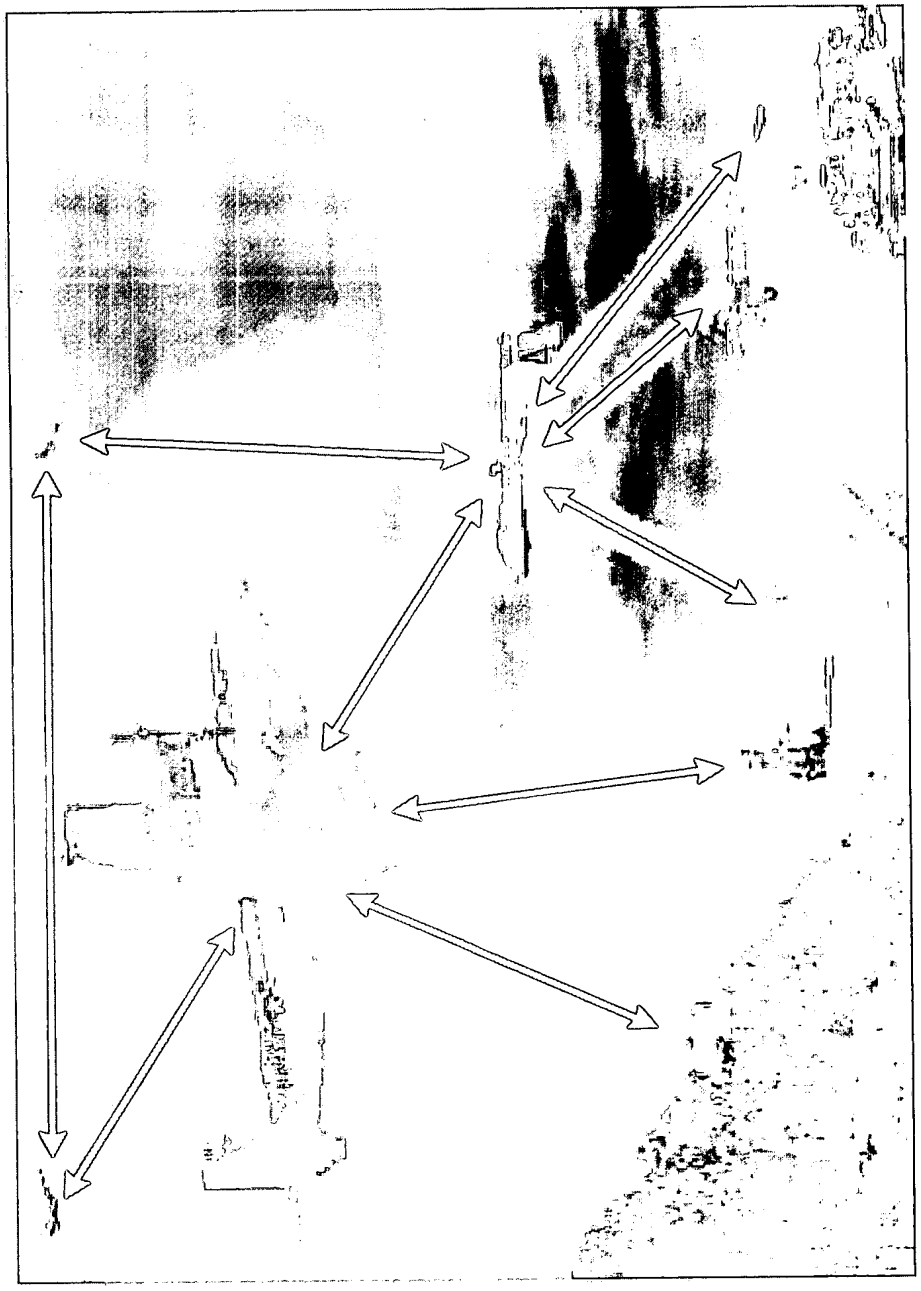


FIG. 2A

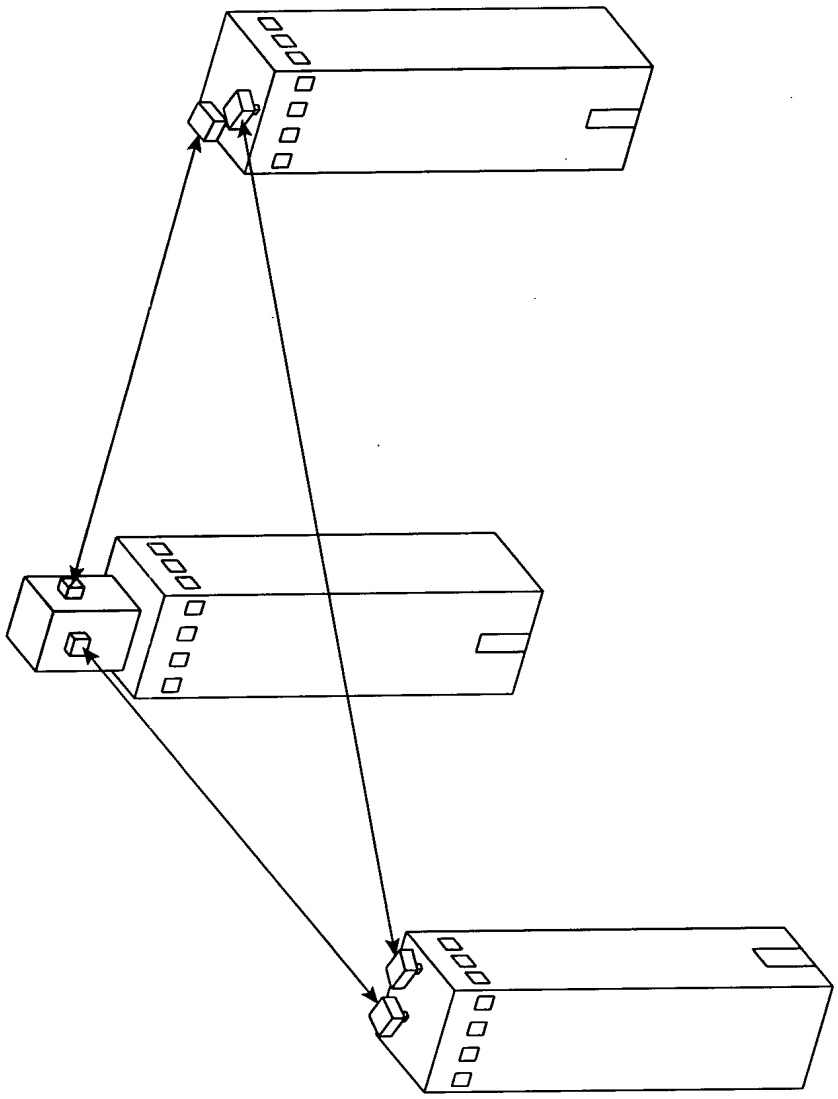


FIG. 2B

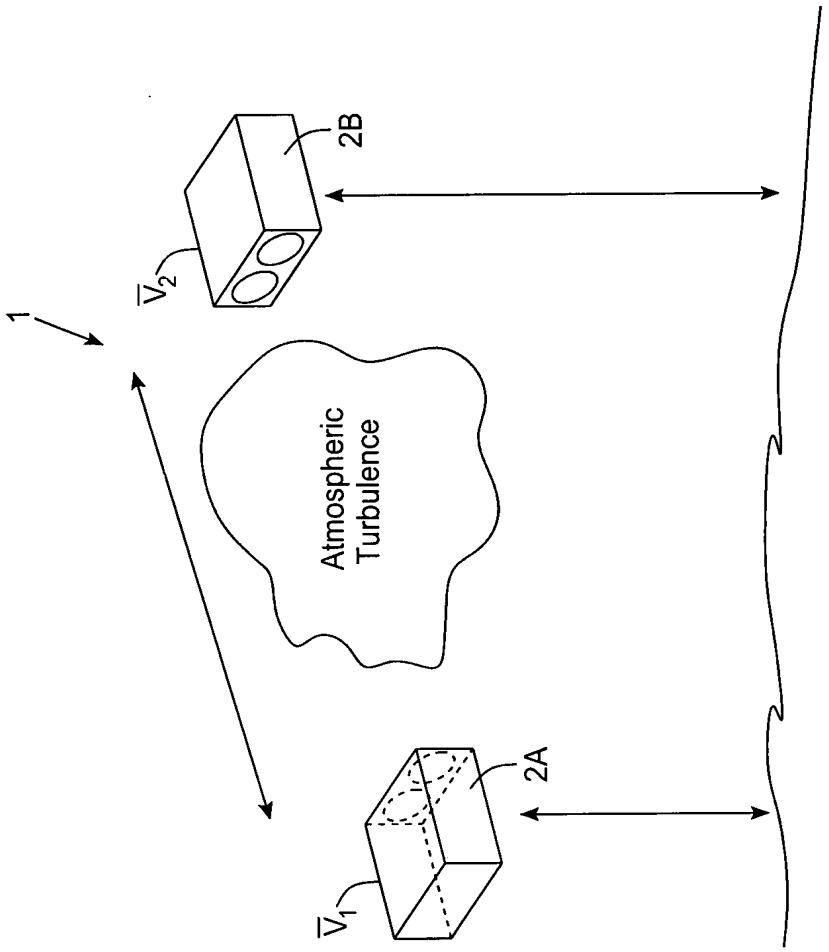


FIG. 3A

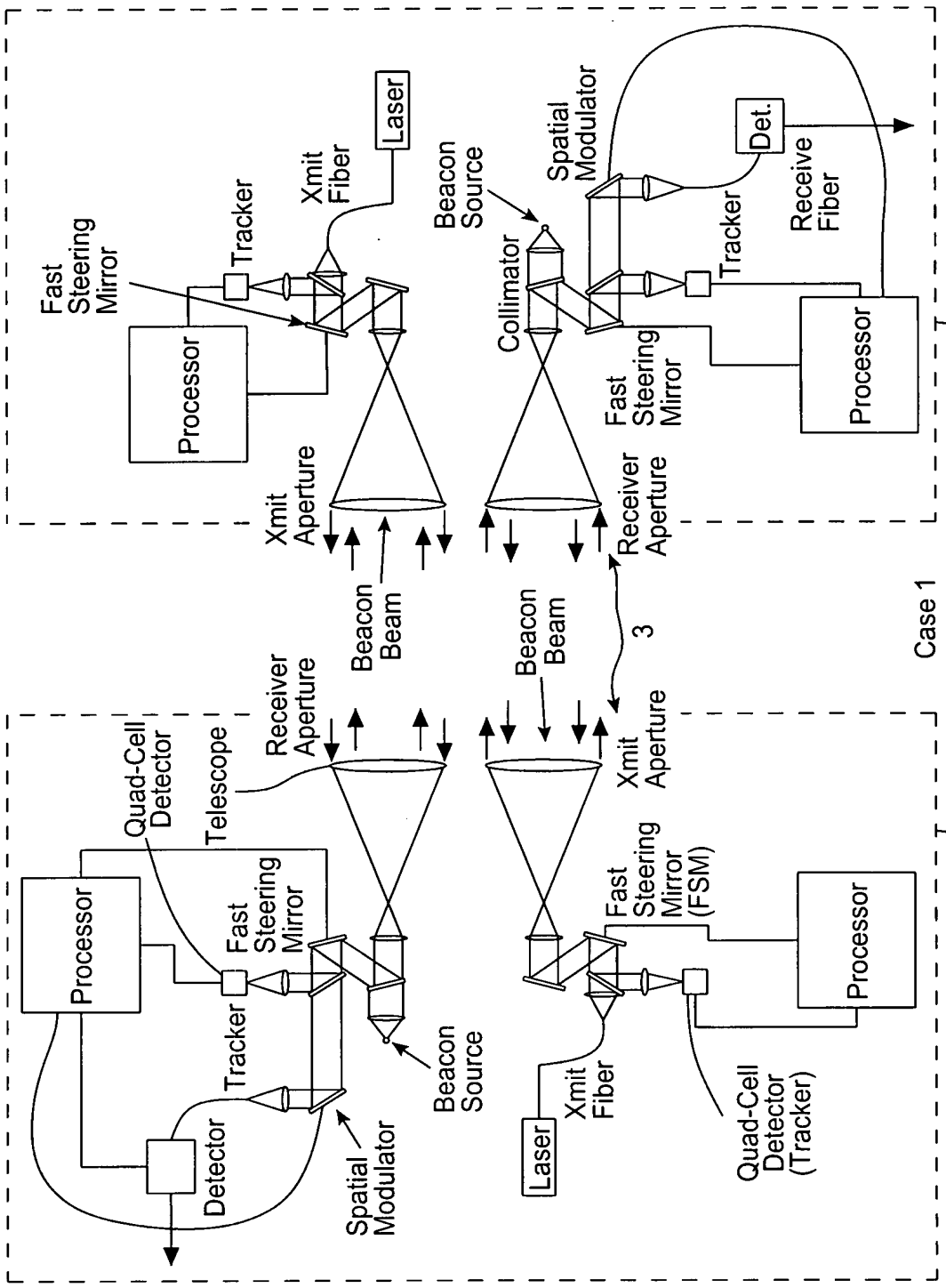

Fast Steering Mirror
Tracker
Xmit Fiber
Laser
Beacon Source
Spatial Modulator
Det.
Receive Fiber
Collimator
Tracker
Processor
Fast Steering Mirror
Xmit Aperture
Receiver Aperture
Beacon Beam
Beacon Beam
3
Case 1
Receiver Aperture
Quad-Cell Detector
Telescope
Xmit Aperture
Processor
Fast Steering Mirror
Tracker
Detector
Spatial Modulator
Beacon Source
Fast Steering Mirror (FSM)
Processor
Laser
Xmit Fiber
Quad-Cell Detector (Tracker)
2A
2B
1

FIG. 3B

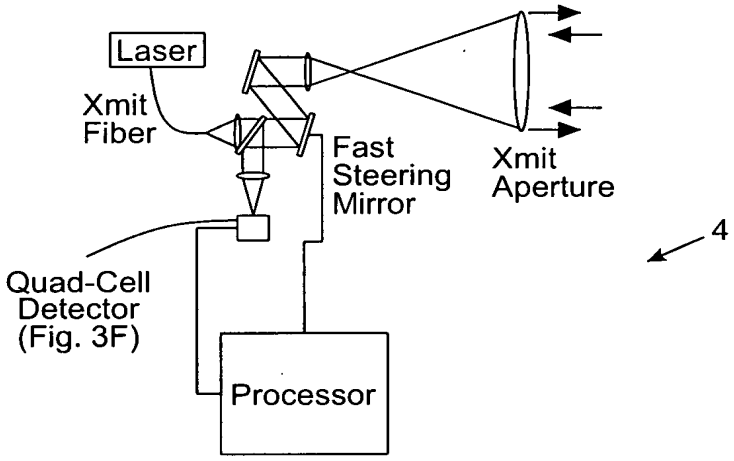

Laser
Xmit
Fiber
Fast
Steering
Mirror
Xmit
Aperture
4
Quad-Cell
Detector
(Fig. 3F)
Processor

FIG. 3C

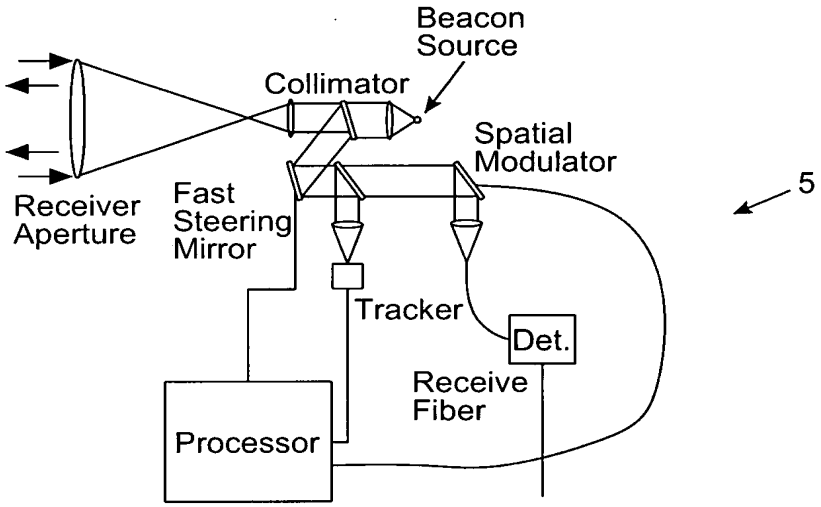

Beacon
Source
Collimator
Spatial
Modulator
5
Receiver
Aperture
Fast
Steering
Mirror
Tracker
Det.
Receive
Fiber
Processor

FIG. 3D

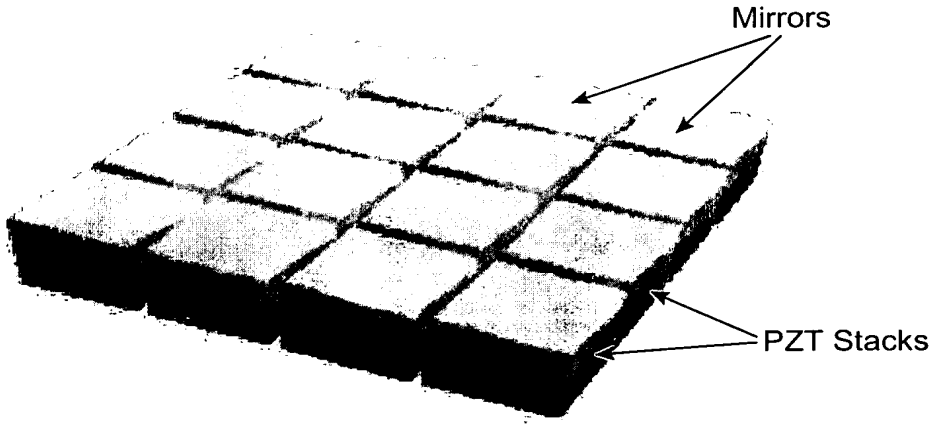

Mirrors
PZT Stacks

FIG. 3E

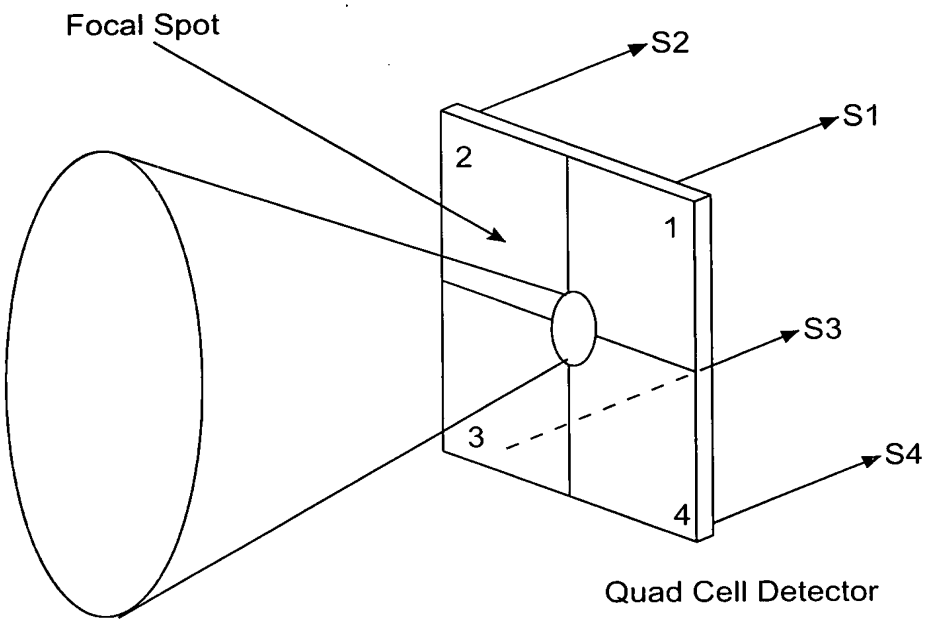
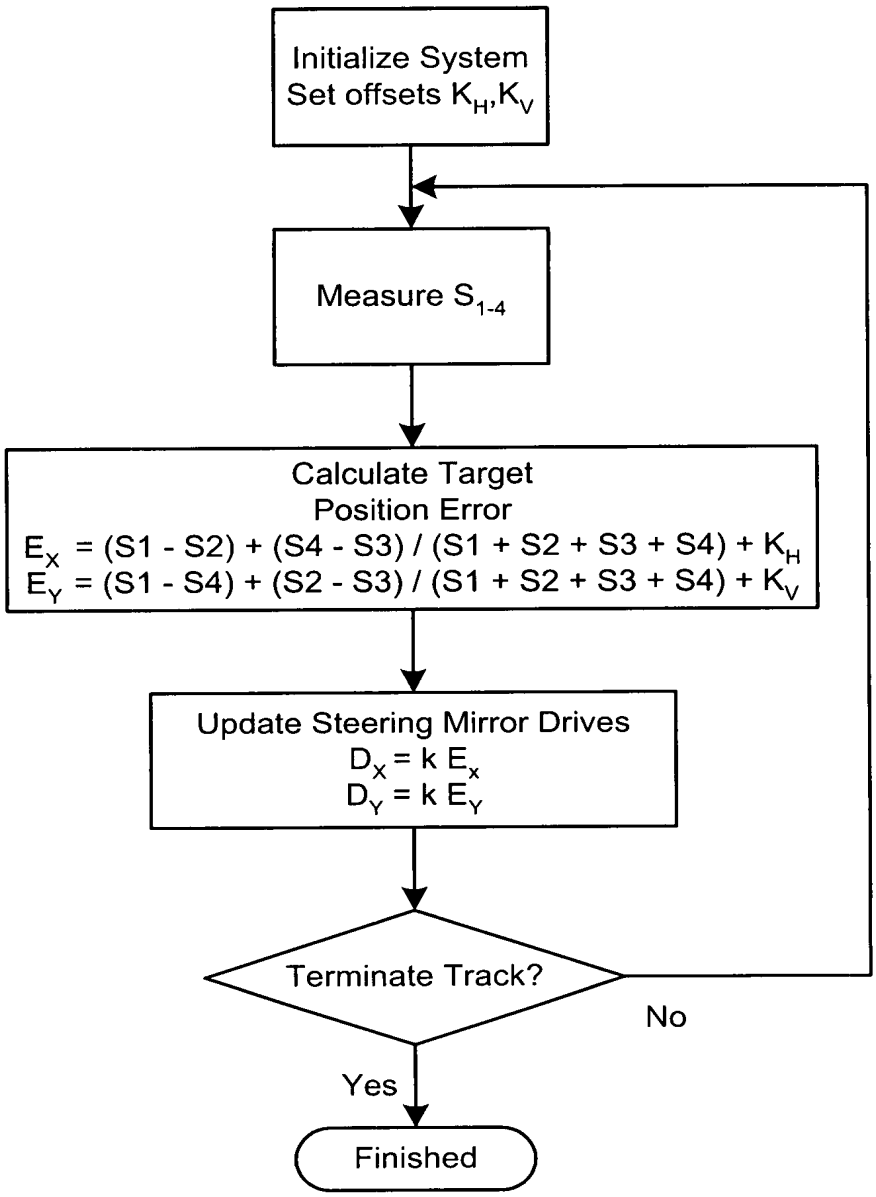

Focal Spot
S2
S1
2
1
S3
3
S4
4
Quad Cell Detector

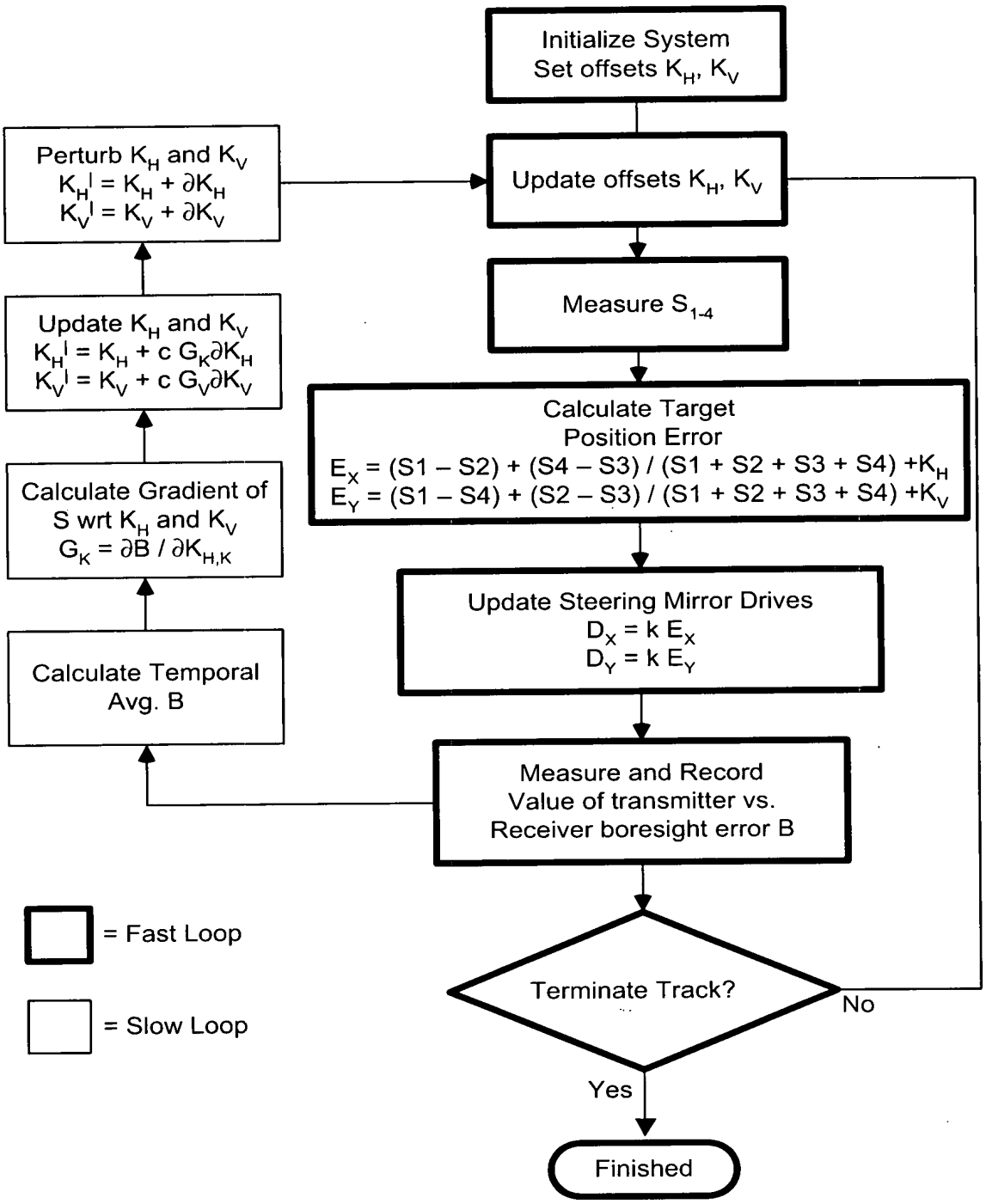
FIG. 3F



Proportional Control

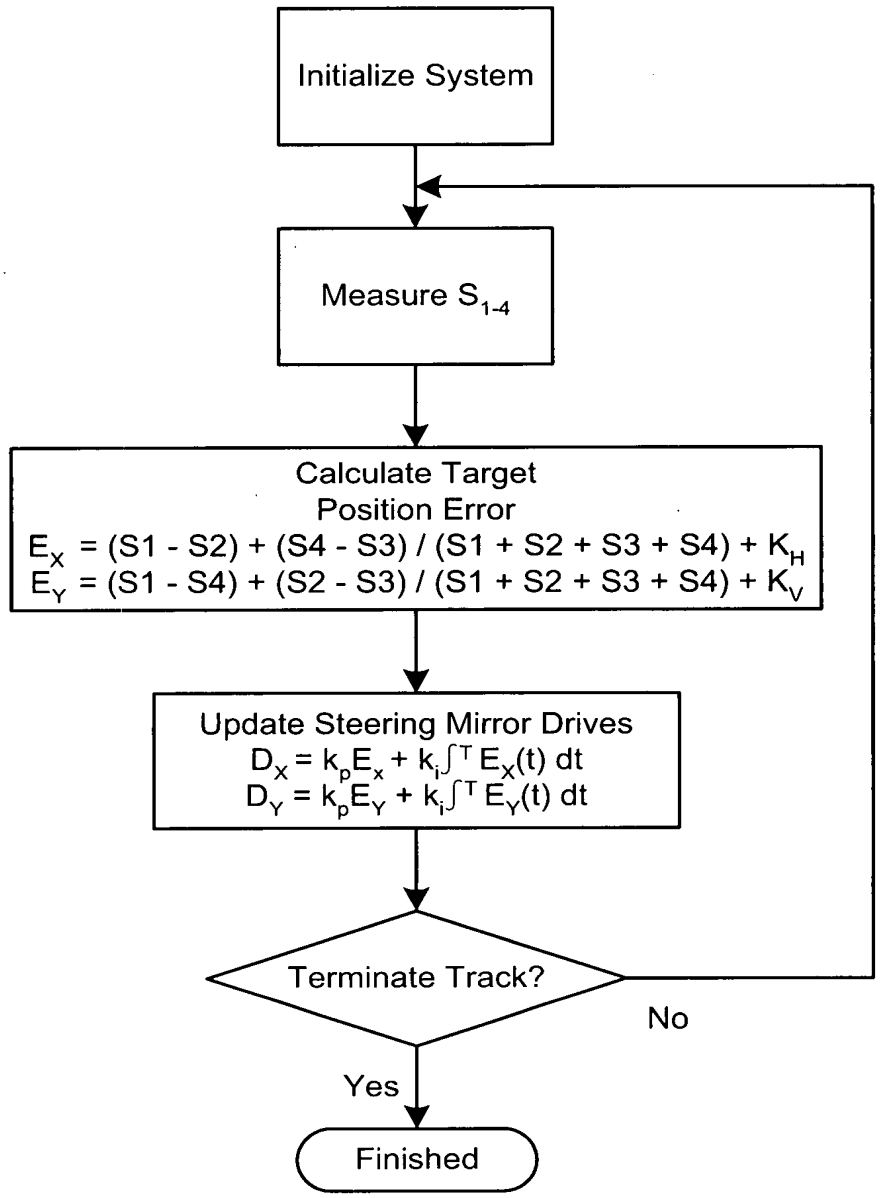
Transmitter

FIG. 4A



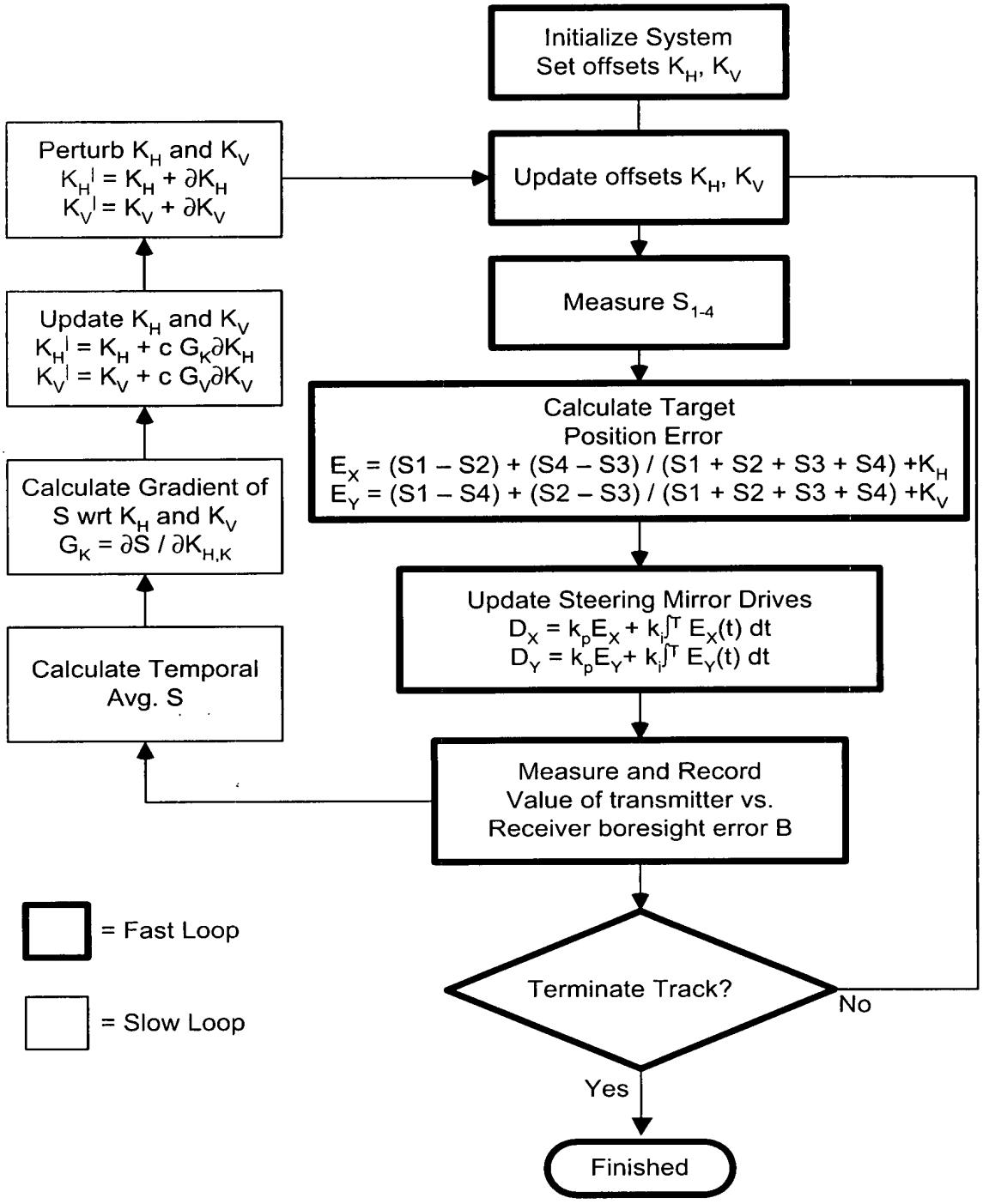
Transmitter Proportional Control

FIG. 4A'



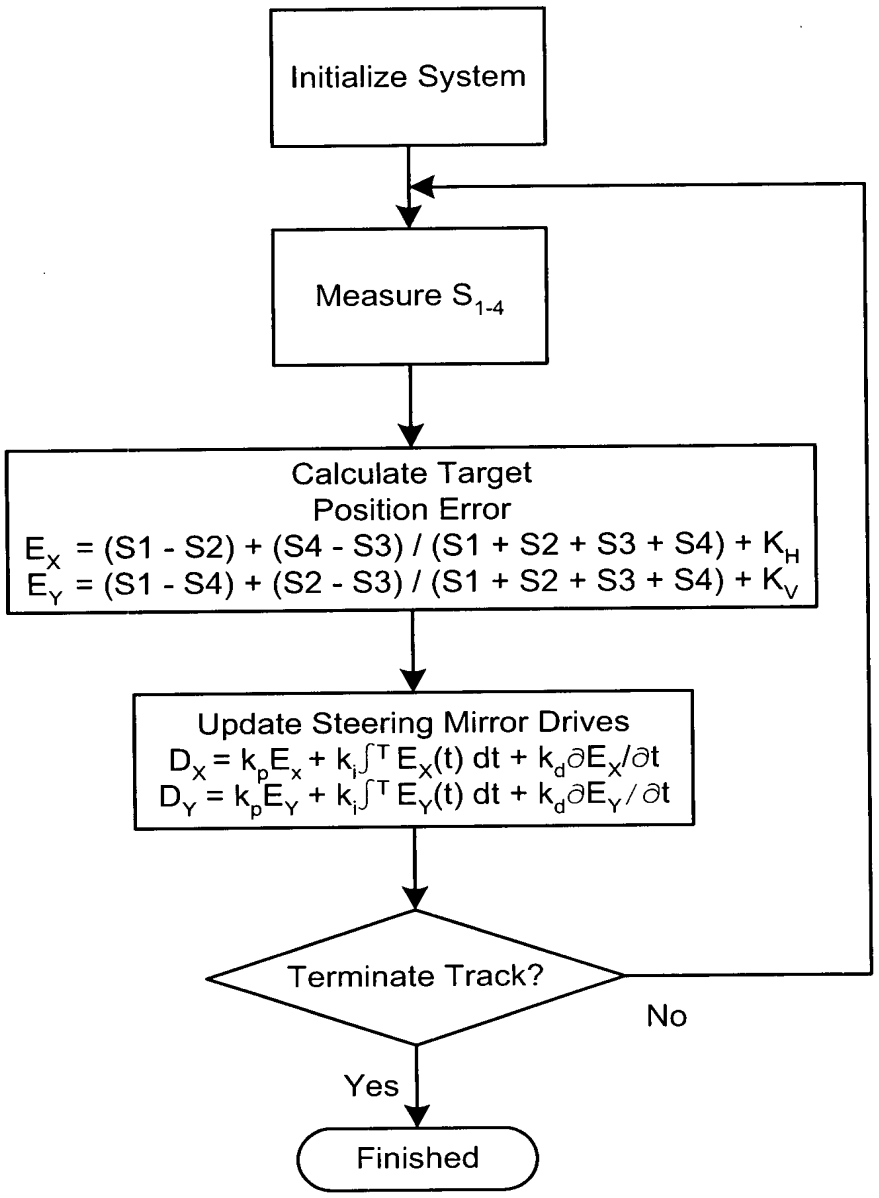
Proportional Plus Integral Control

FIG. 4B



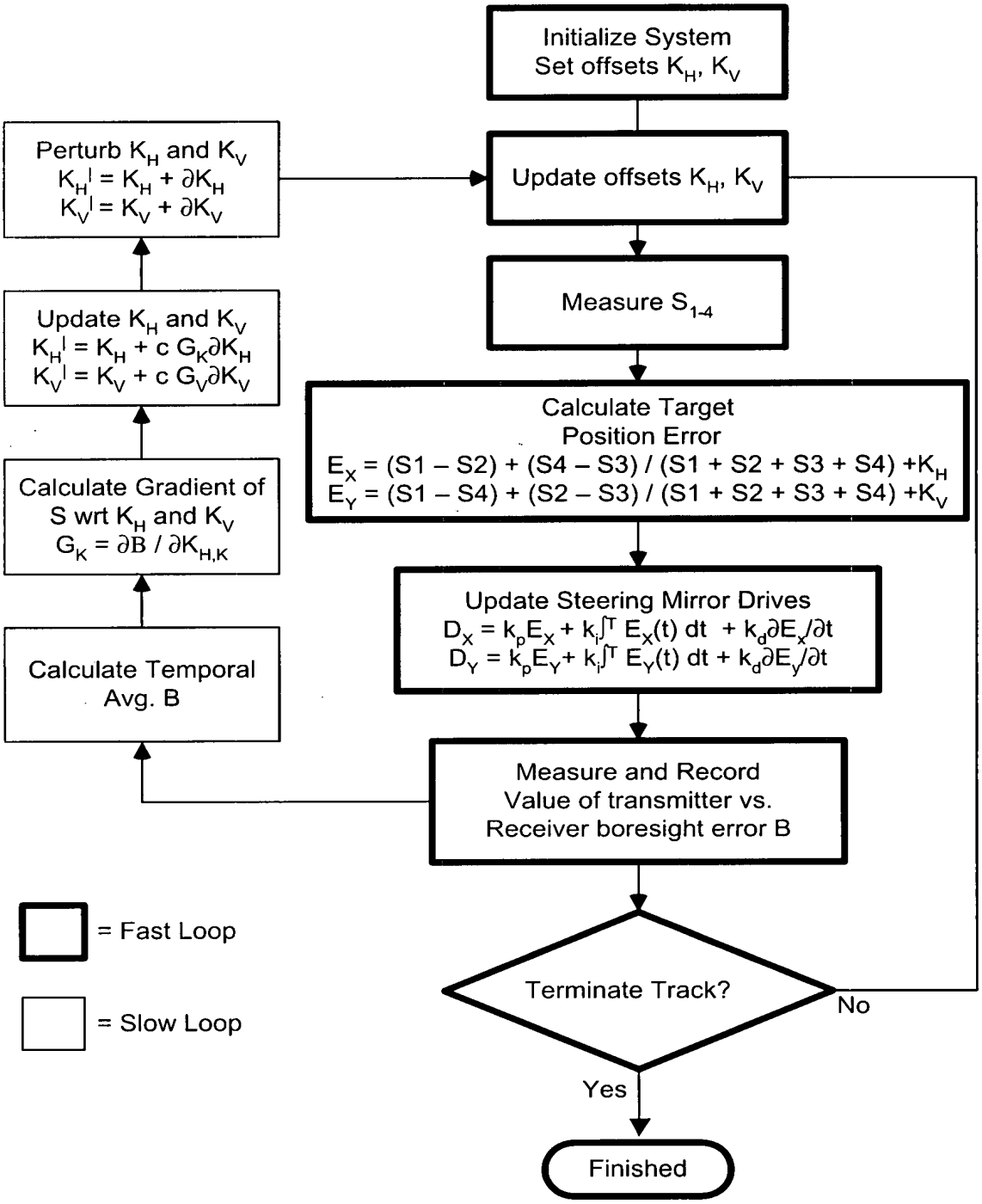
Transmitter Proportional plus Integral Control

FIG. 4B'



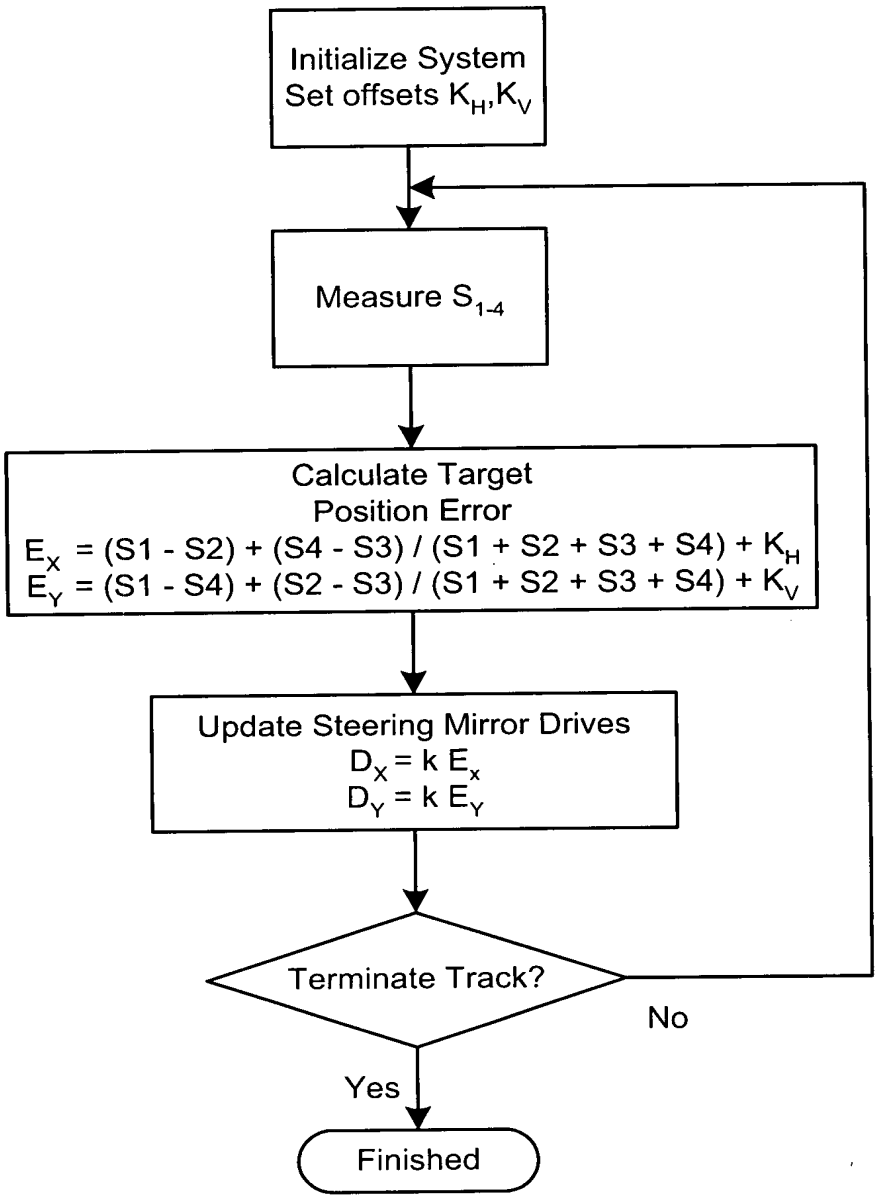
Proportional Plus Integral Control Plus Derivative

FIG. 4C



Transmitter Proportional plus Integral Control plus Derivative

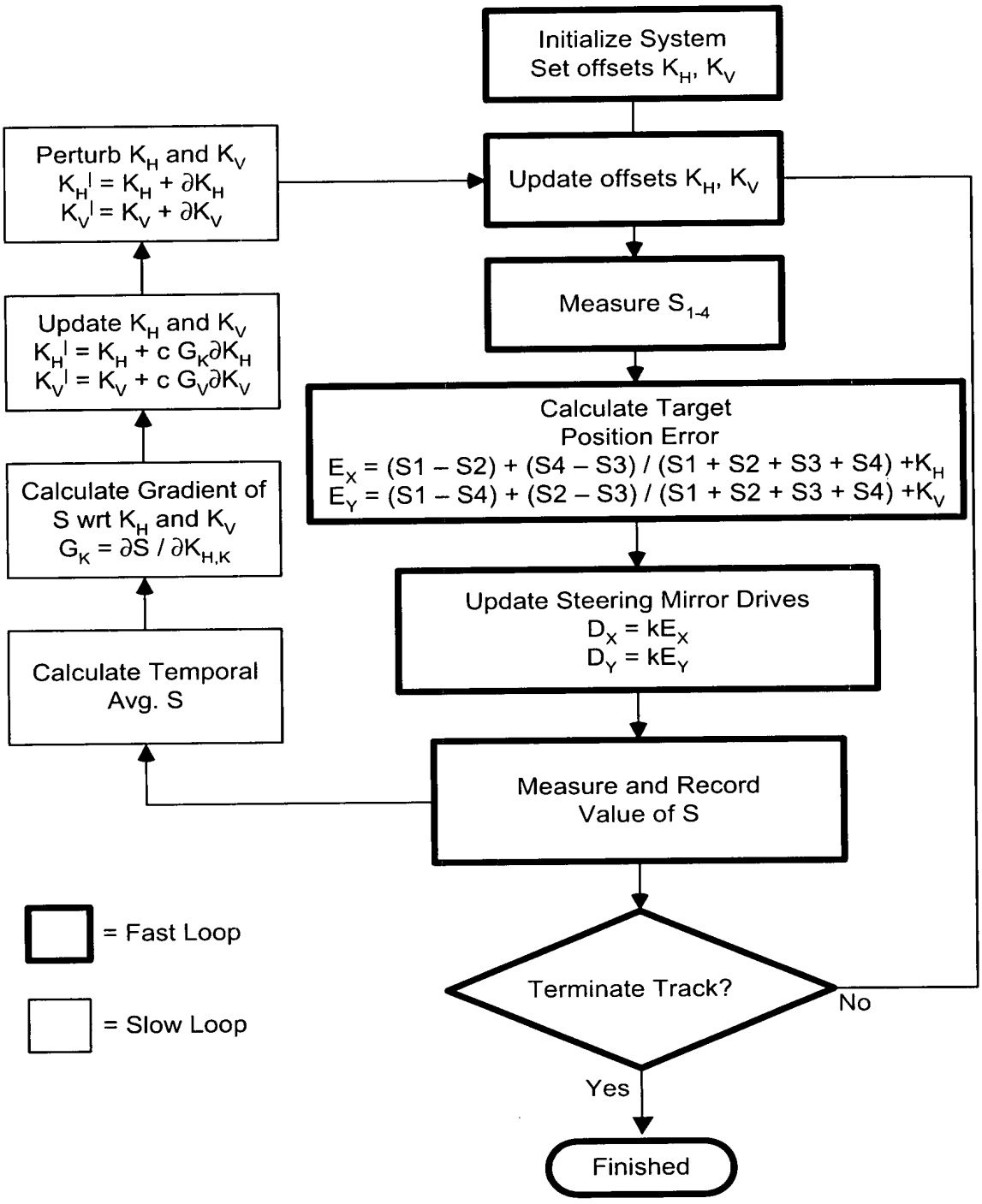
FIG. 4C'



Proportional Control

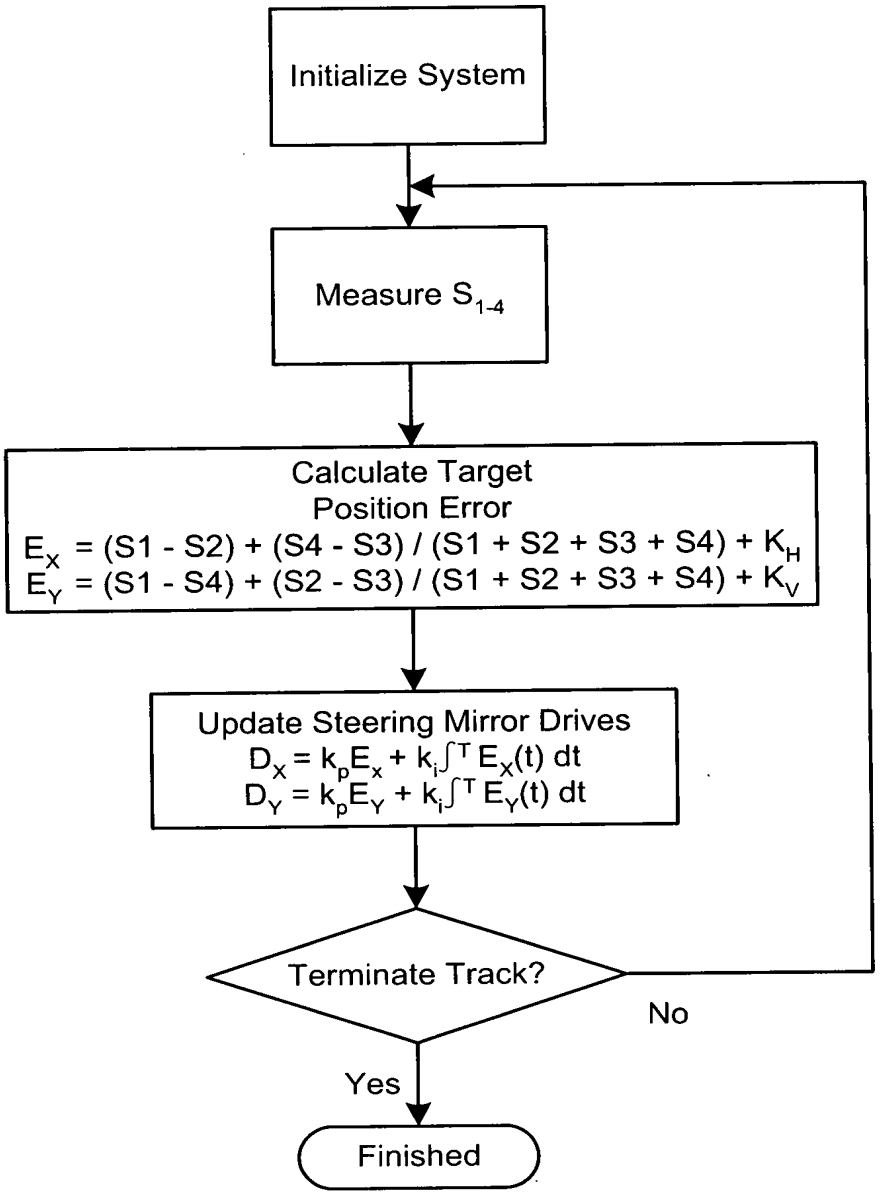
Receiver

FIG. 4D



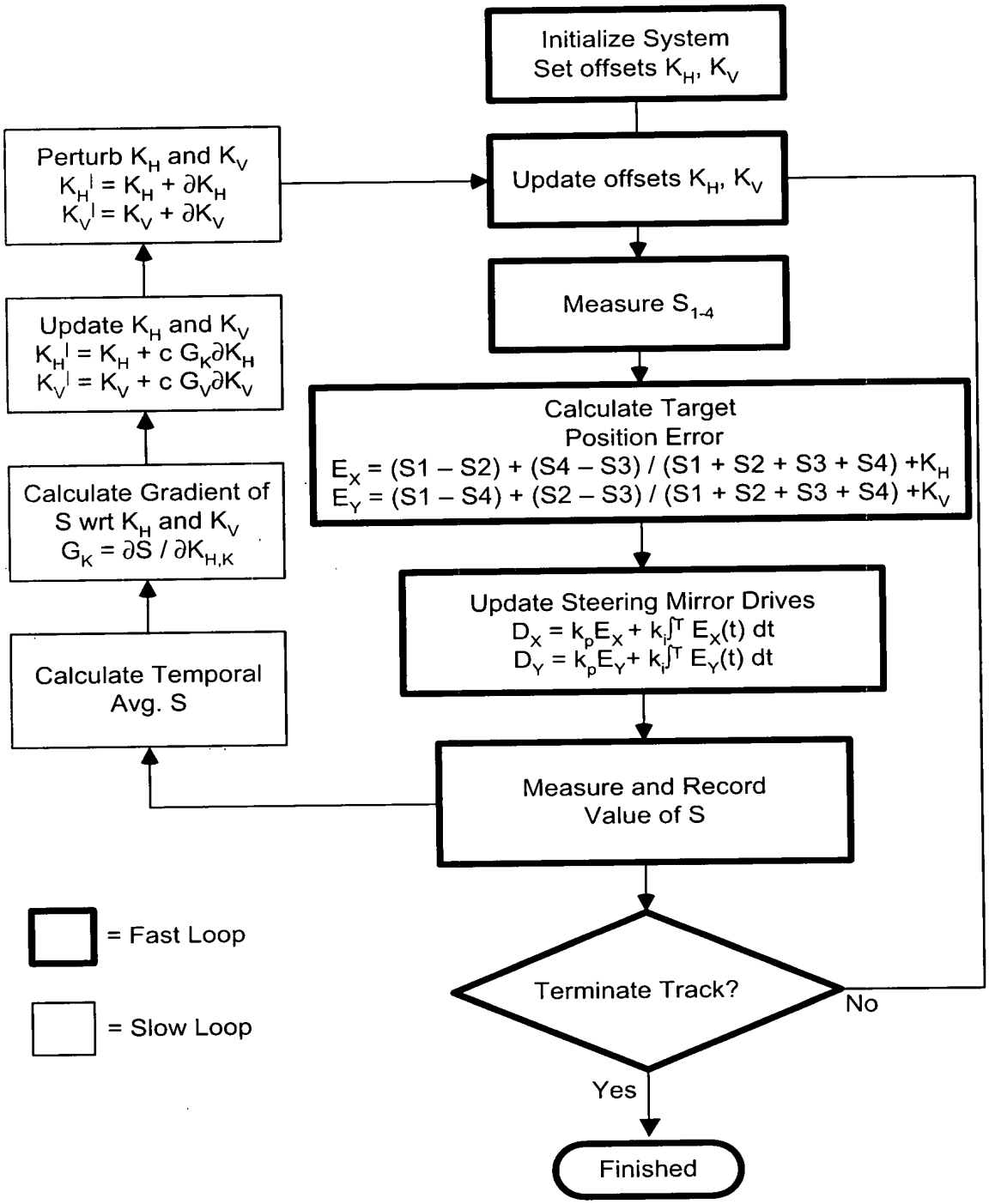
Receiver Proportional Control

FIG. 4D'



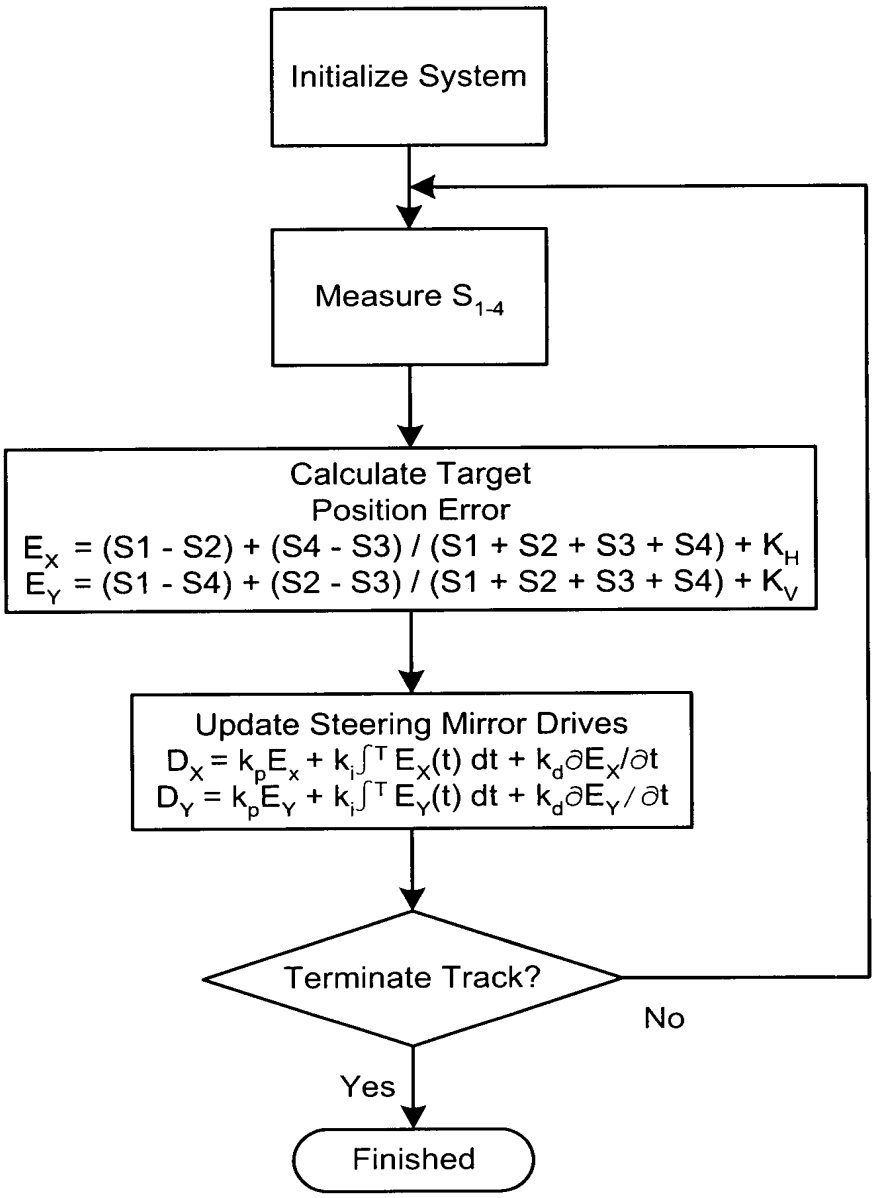
Proportional Plus Integral Control

FIG. 4E



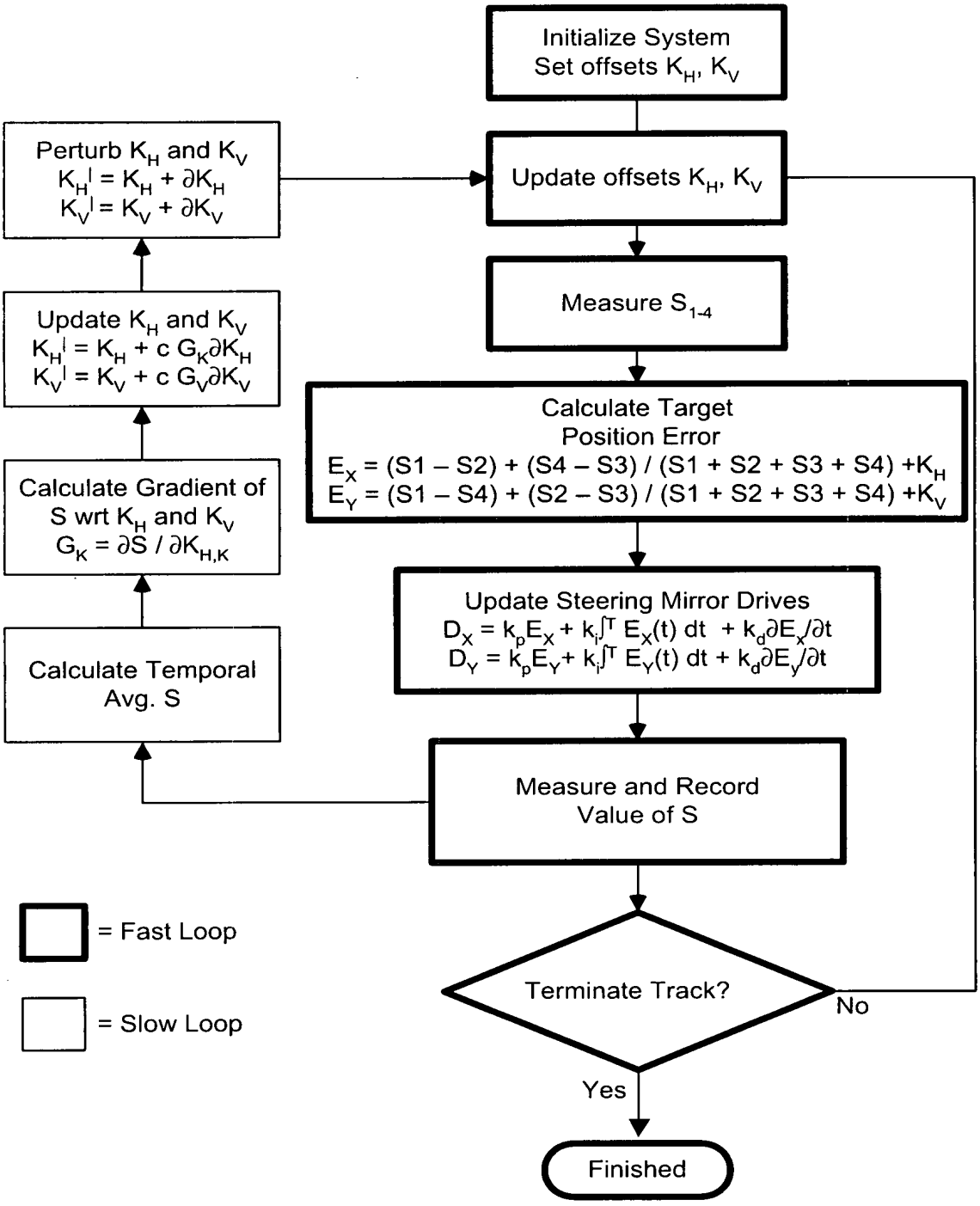
Receiver Proportional plus Integral Control

FIG. 4E'



Proportional Plus Integral Control Plus Derivative

FIG. 4F



Receiver Proportional plus Integral Control plus Derivative

FIG. 4F'

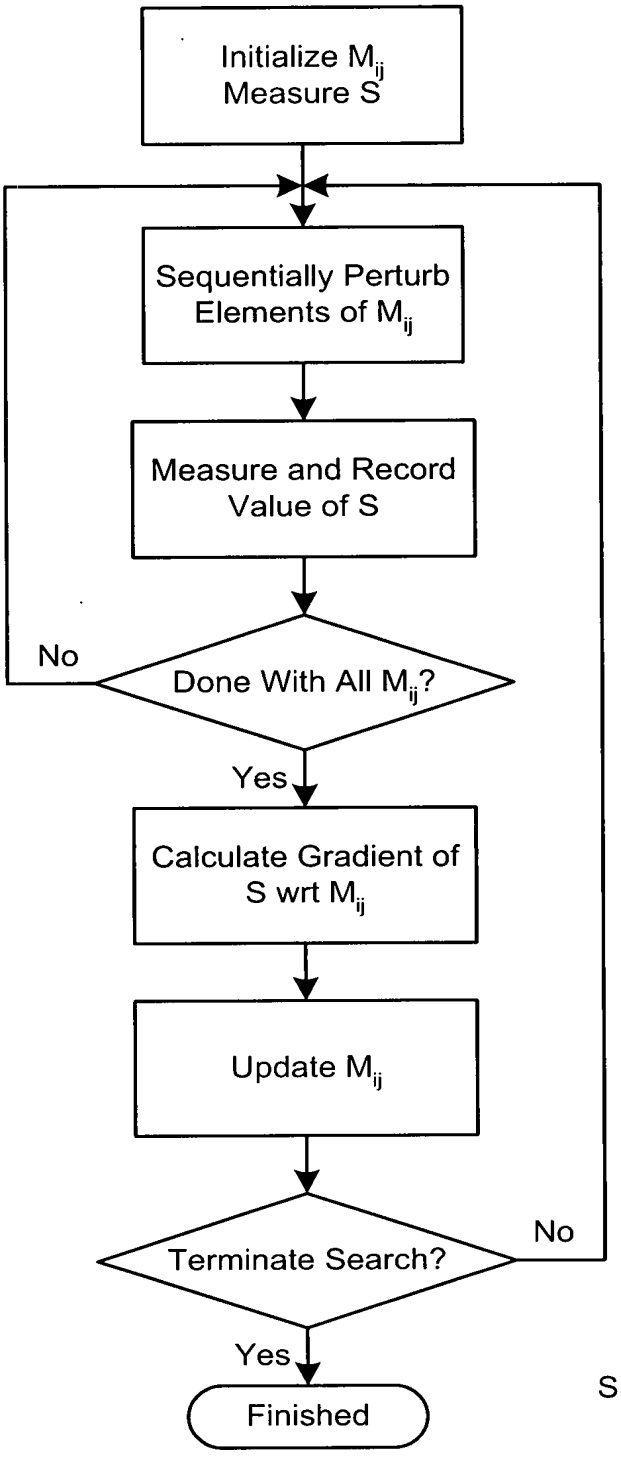

Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
No
Done With All M_{ij}?
Yes
Calculate Gradient of S wrt M_{ij}
Update M_{ij}
No
Terminate Search?
Yes
Finished
SPM Control Signal Generation Algorithm

FIG. 5A

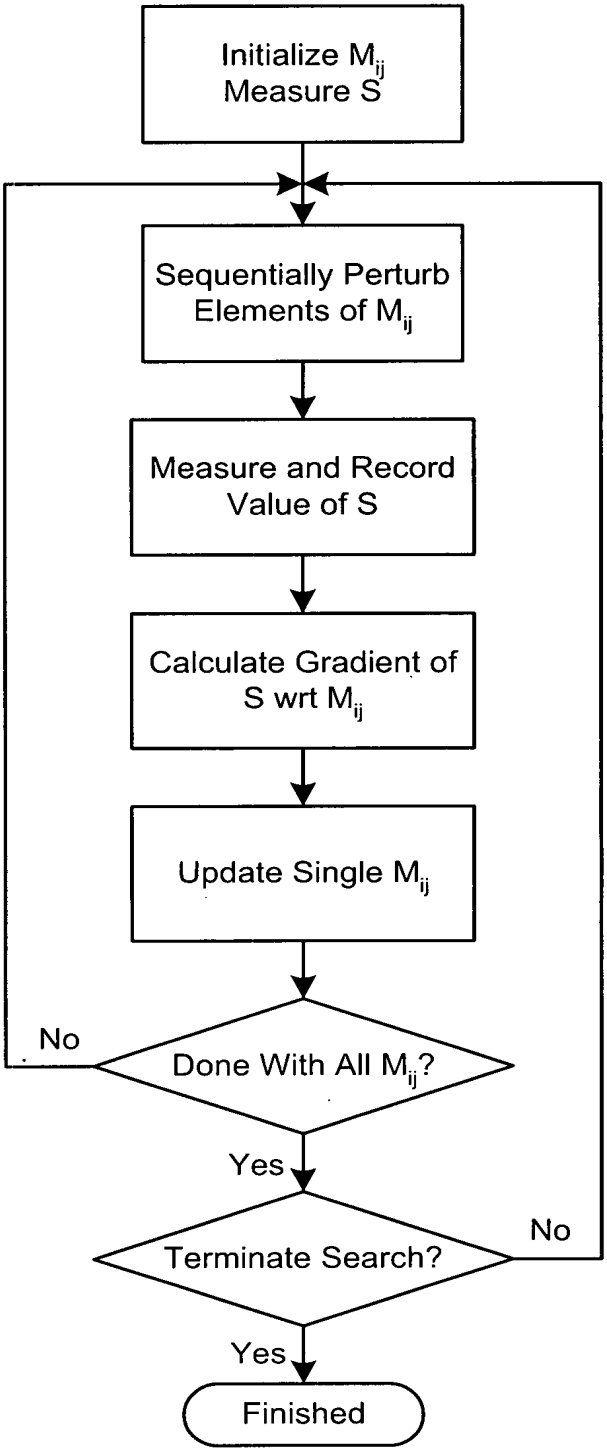

Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt M_{ij}
Update Single M_{ij}
Done With All M_{ij}?
No
Yes
Terminate Search?
No
Yes
Finished

FIG. 5B

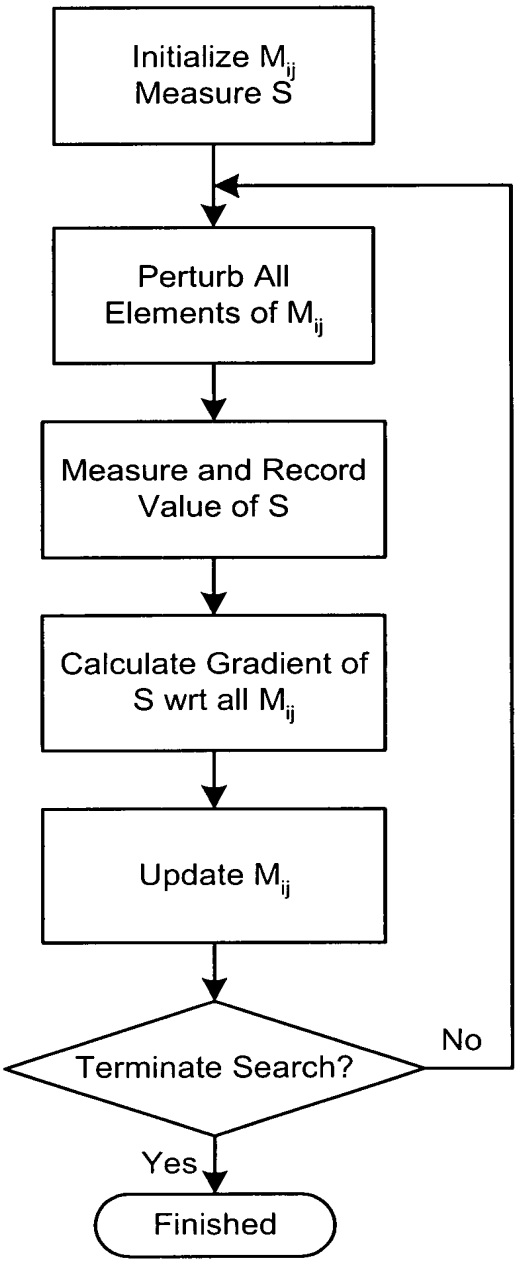

Initialize M_{ij}
Measure S
Perturb All
Elements of M_{ij}
Measure and Record
Value of S
Calculate Gradient of
S wrt all M_{ij}
Update M_{ij}
Terminate Search?
No
Yes
Finished

FIG. 5C

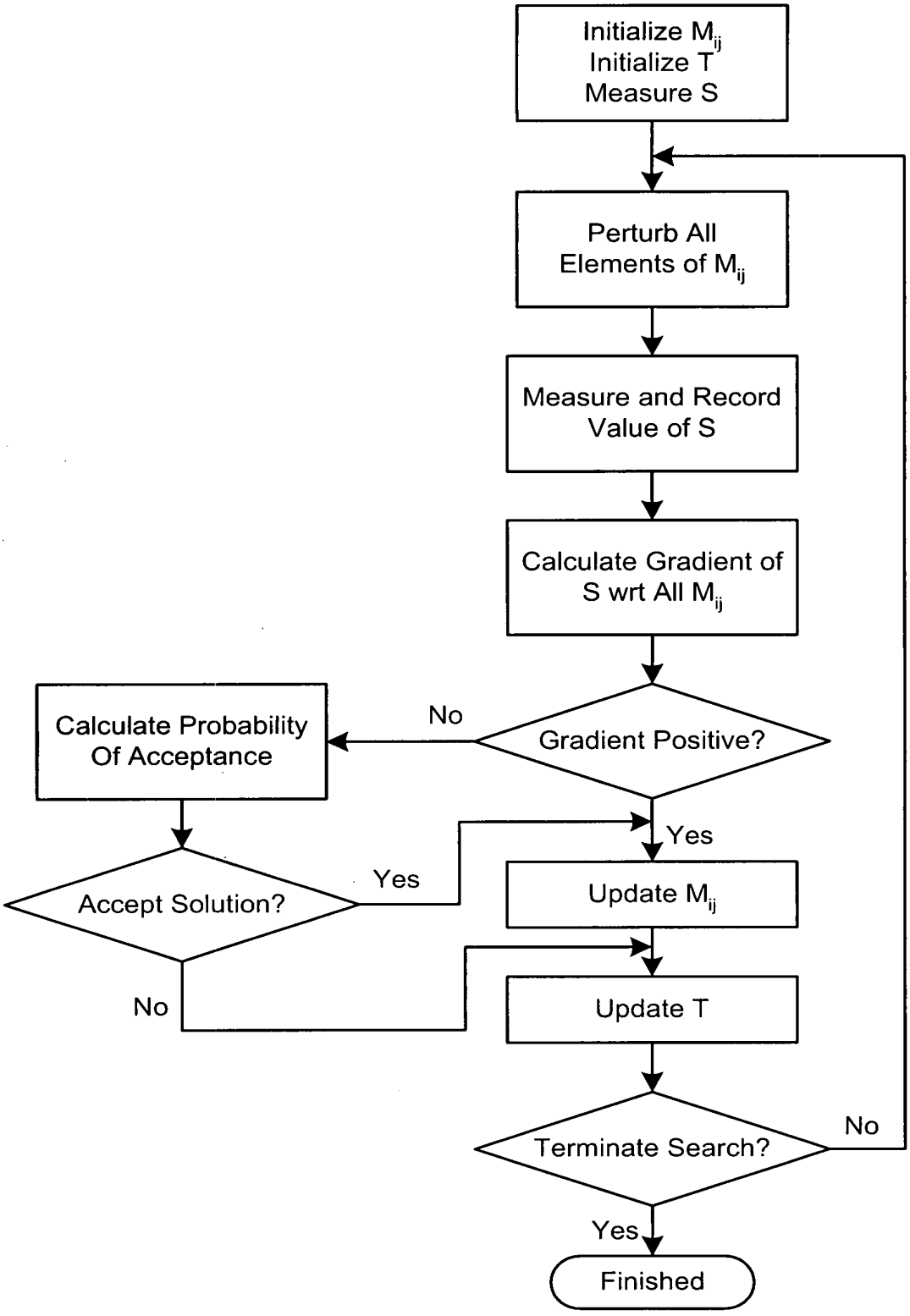

Initialize M_{ij}
Initialize T
Measure S
Perturb All Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt All M_{ij}
Gradient Positive?
No
Calculate Probability Of Acceptance
Accept Solution?
Yes
No
Yes
Update M_{ij}
Update T
Terminate Search?
No
Yes
Finished

FIG. 5D

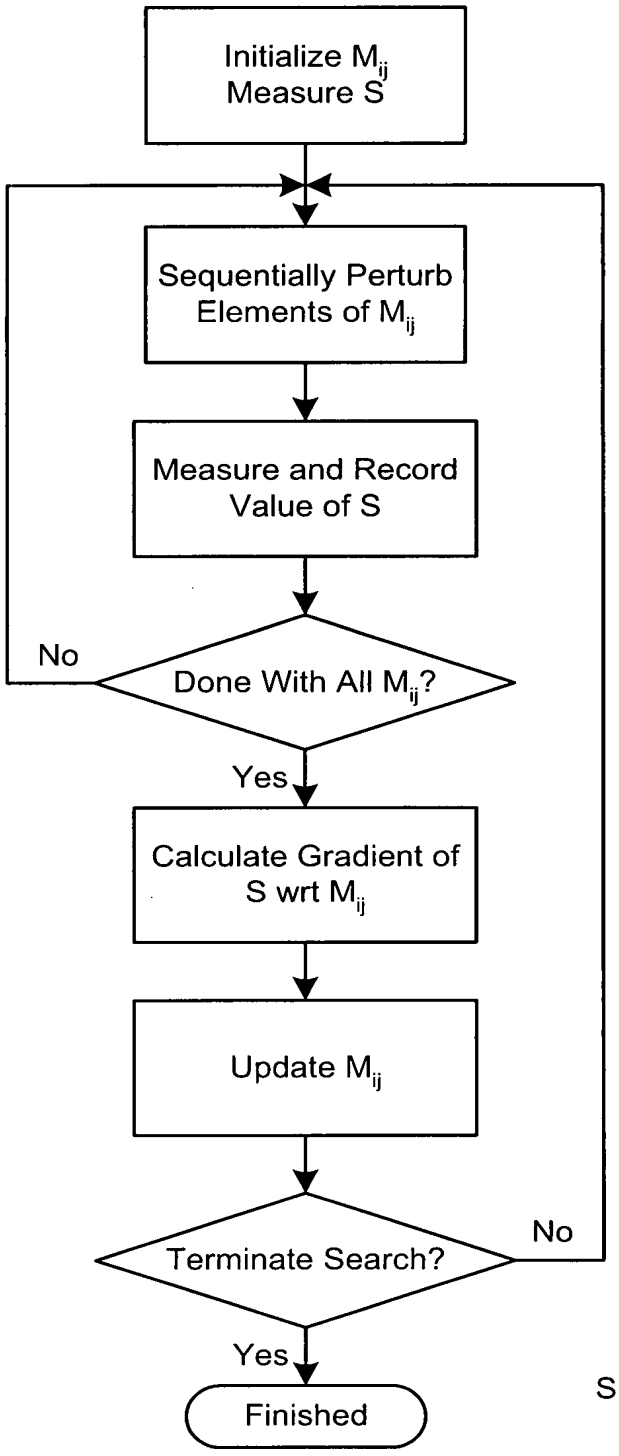

Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
Done With All M_{ij}?
No
Yes
Calculate Gradient of S wrt M_{ij}
Update M_{ij}
Terminate Search?
No
Yes
Finished
SIM Control Signal Generation Algorithm

FIG. 6A

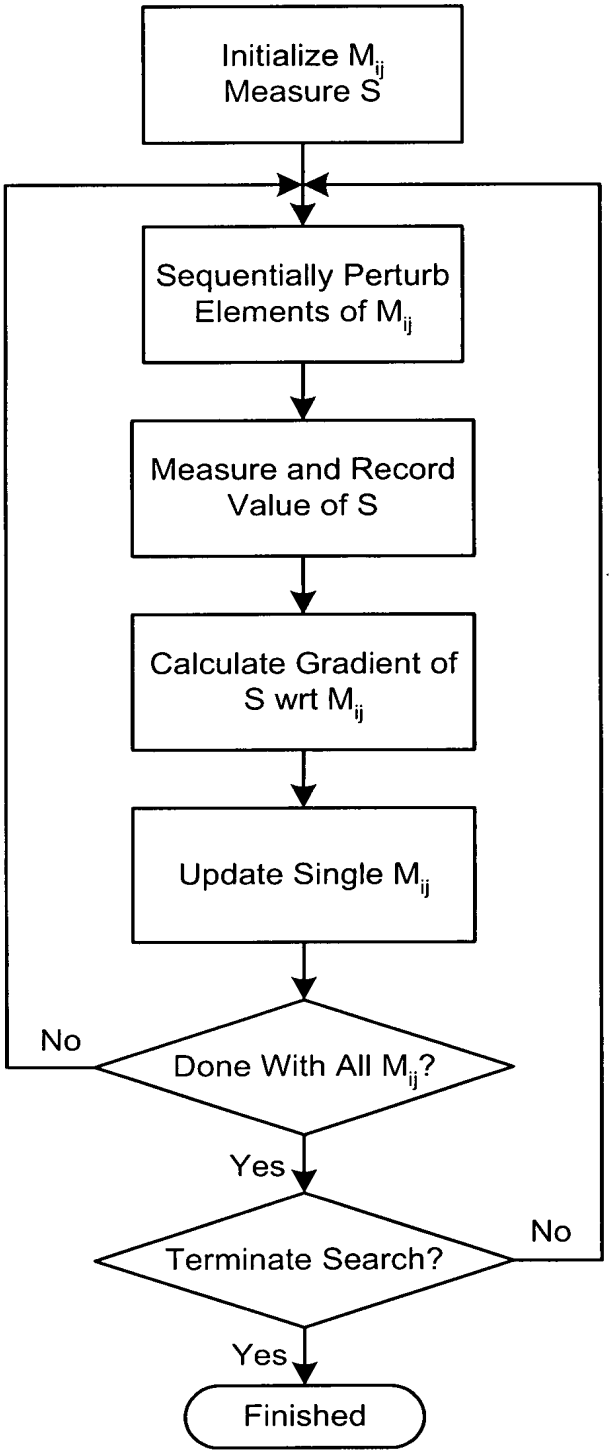

Initialize M_{ij}
Measure S
Sequentially Perturb Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt M_{ij}
Update Single M_{ij}
Done With All M_{ij}?
No
Yes
Terminate Search?
No
Yes
Finished

FIG. 6B

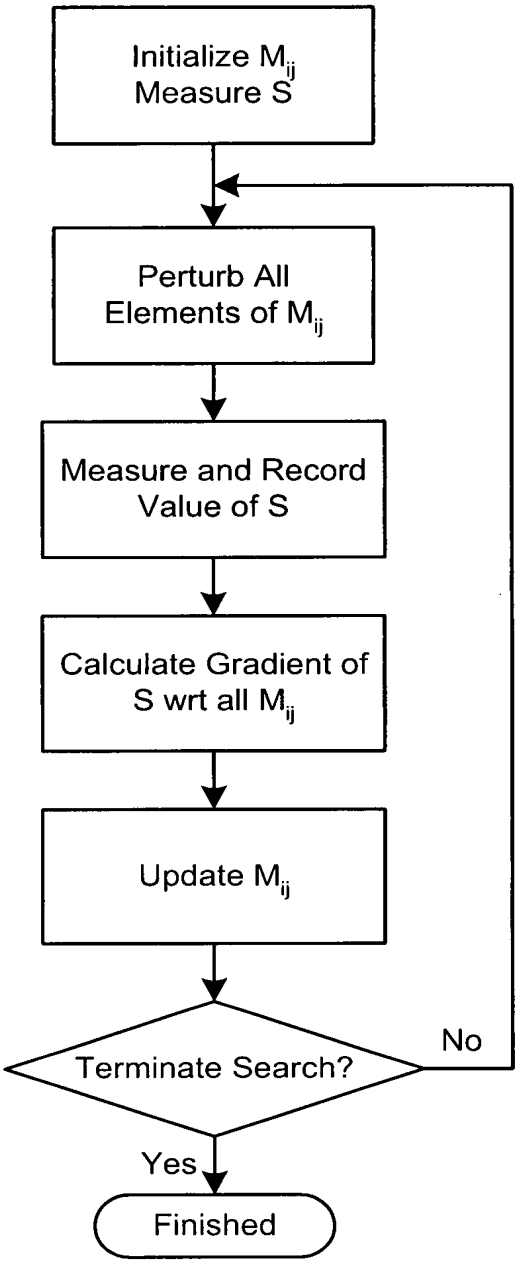

Initialize M_{ij}
Measure S
Perturb All
Elements of M_{ij}
Measure and Record
Value of S
Calculate Gradient of
S wrt all M_{ij}
Update M_{ij}
Terminate Search?
No
Yes
Finished

FIG. 6C

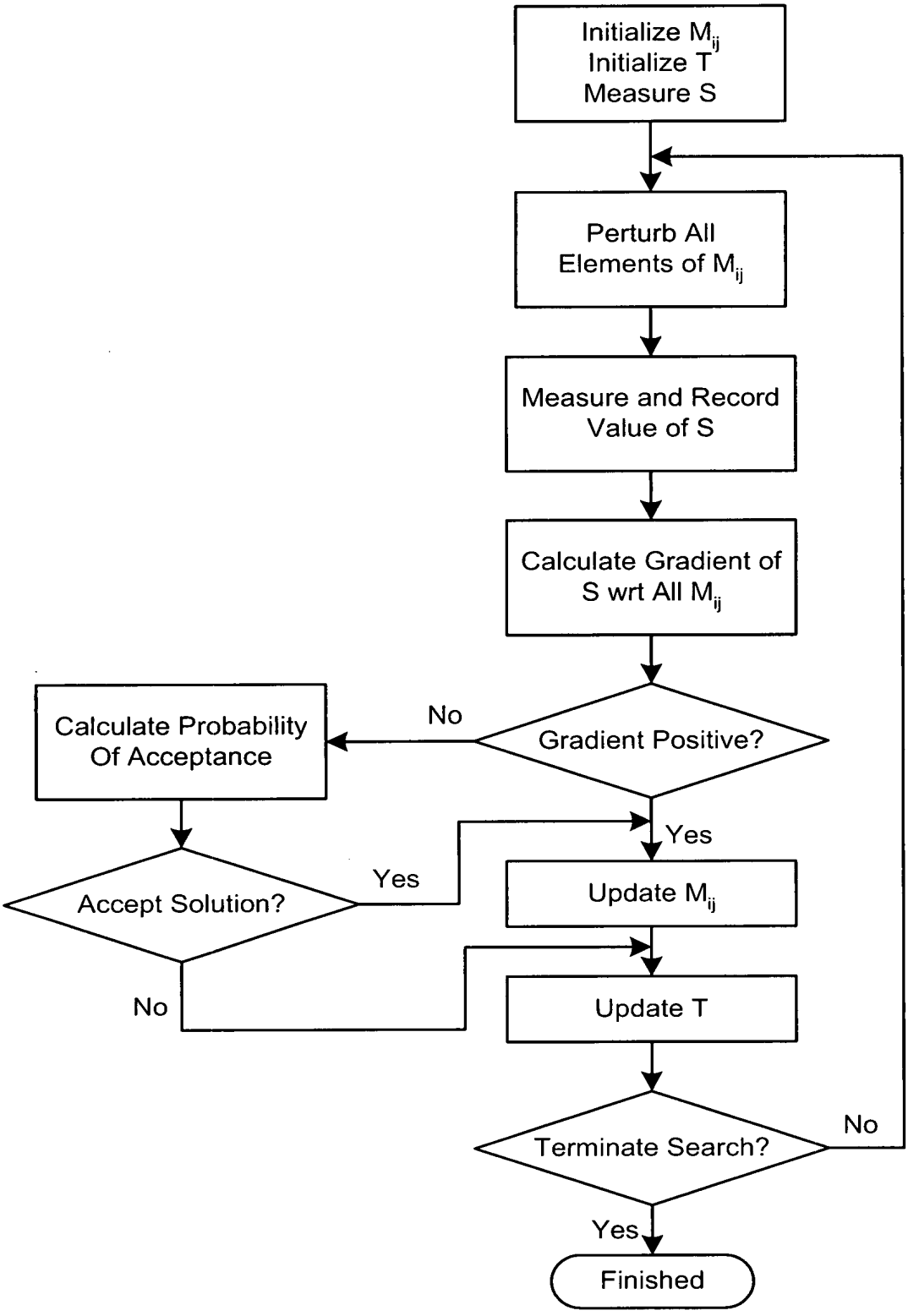

Initialize M_{ij}
Initialize T
Measure S
Perturb All Elements of M_{ij}
Measure and Record Value of S
Calculate Gradient of S wrt All M_{ij}
Gradient Positive?
No
Calculate Probability Of Acceptance
Accept Solution?
Yes
No
Yes
Update M_{ij}
Update T
Terminate Search?
No
Yes
Finished

FIG. 6D

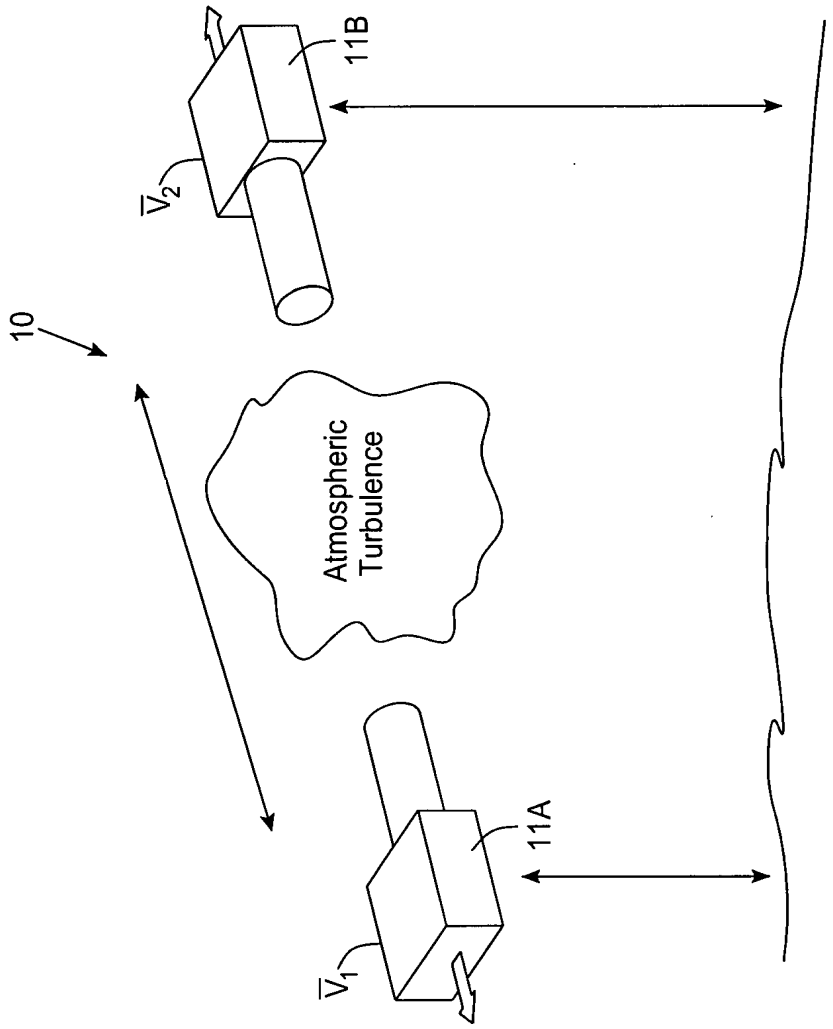


FIG. 7A

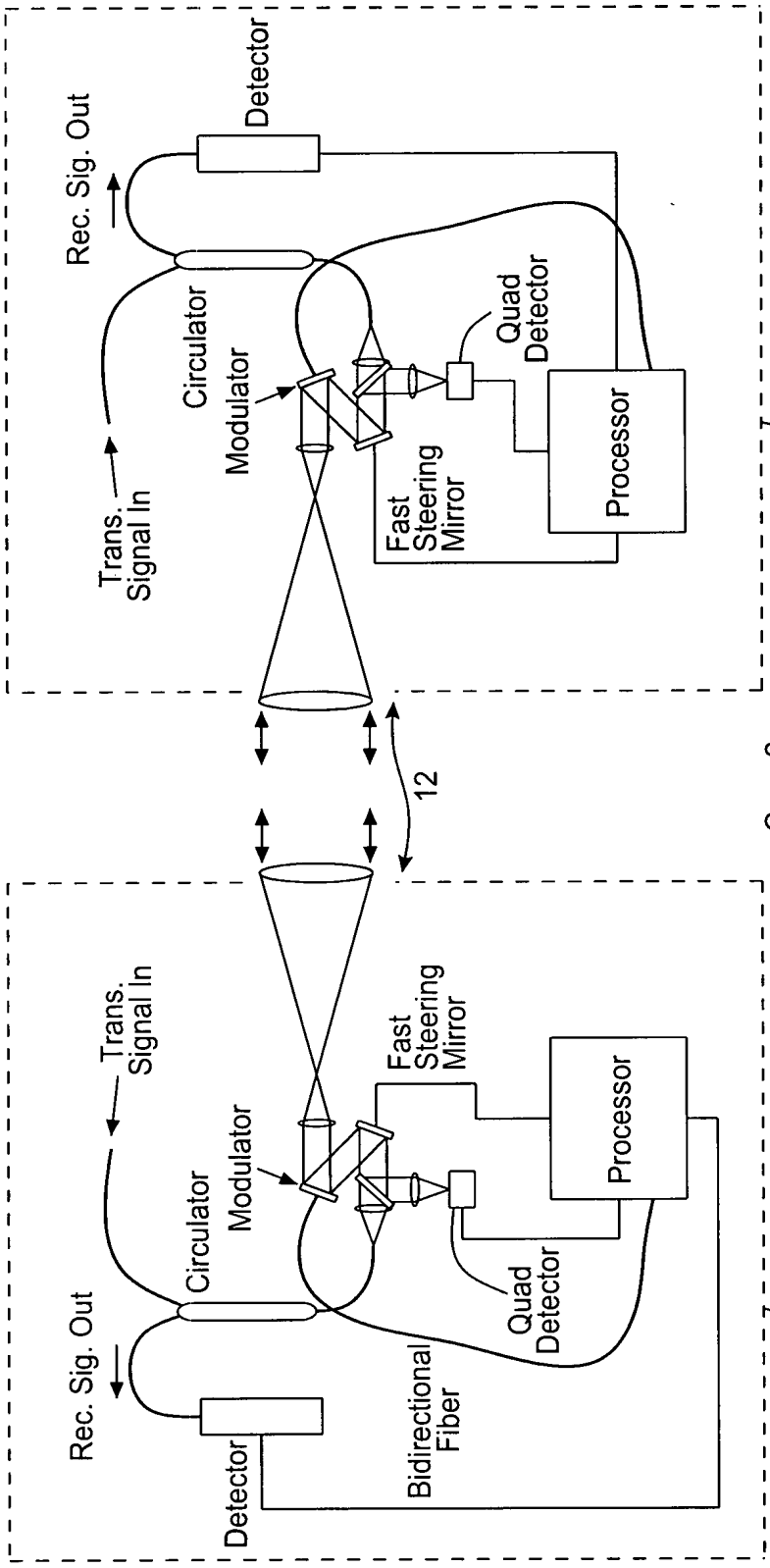

Detector
Rec. Sig. Out
Circulator
Modulator
Quad Detector
Trans. Signal In
Fast Steering Mirror
Processor
11B
12
Case 2
Trans. Signal In
Fast Steering Mirror
Modulator
Processor
Circulator
Quad Detector
Rec. Sig. Out
Bidirectional Fiber
Detector
11A
10

FIG. 7B

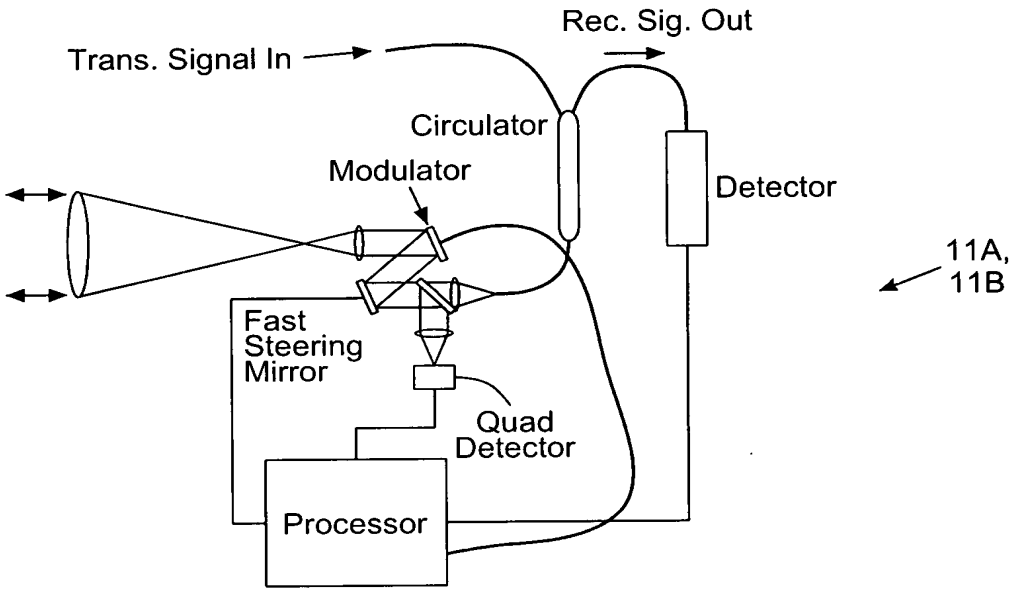

Rec. Sig. Out
Trans. Signal In
Circulator
Modulator
Detector
11A,
11B
Fast
Steering
Mirror
Quad
Detector
Processor

FIG. 7C

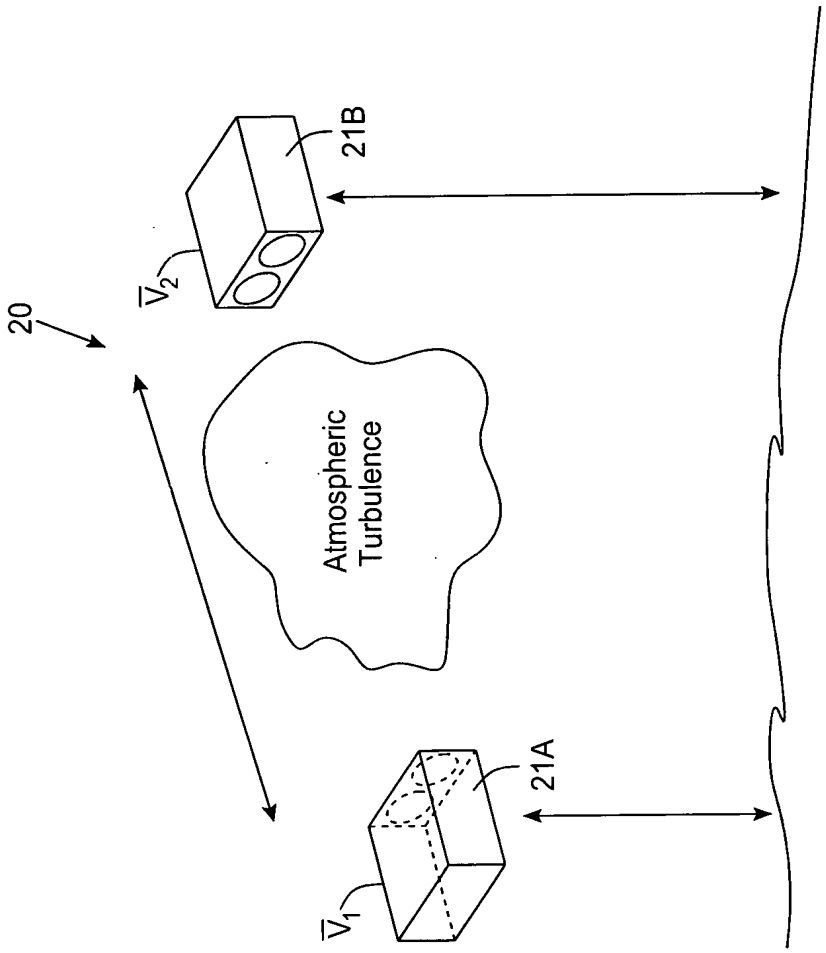


FIG. 8A

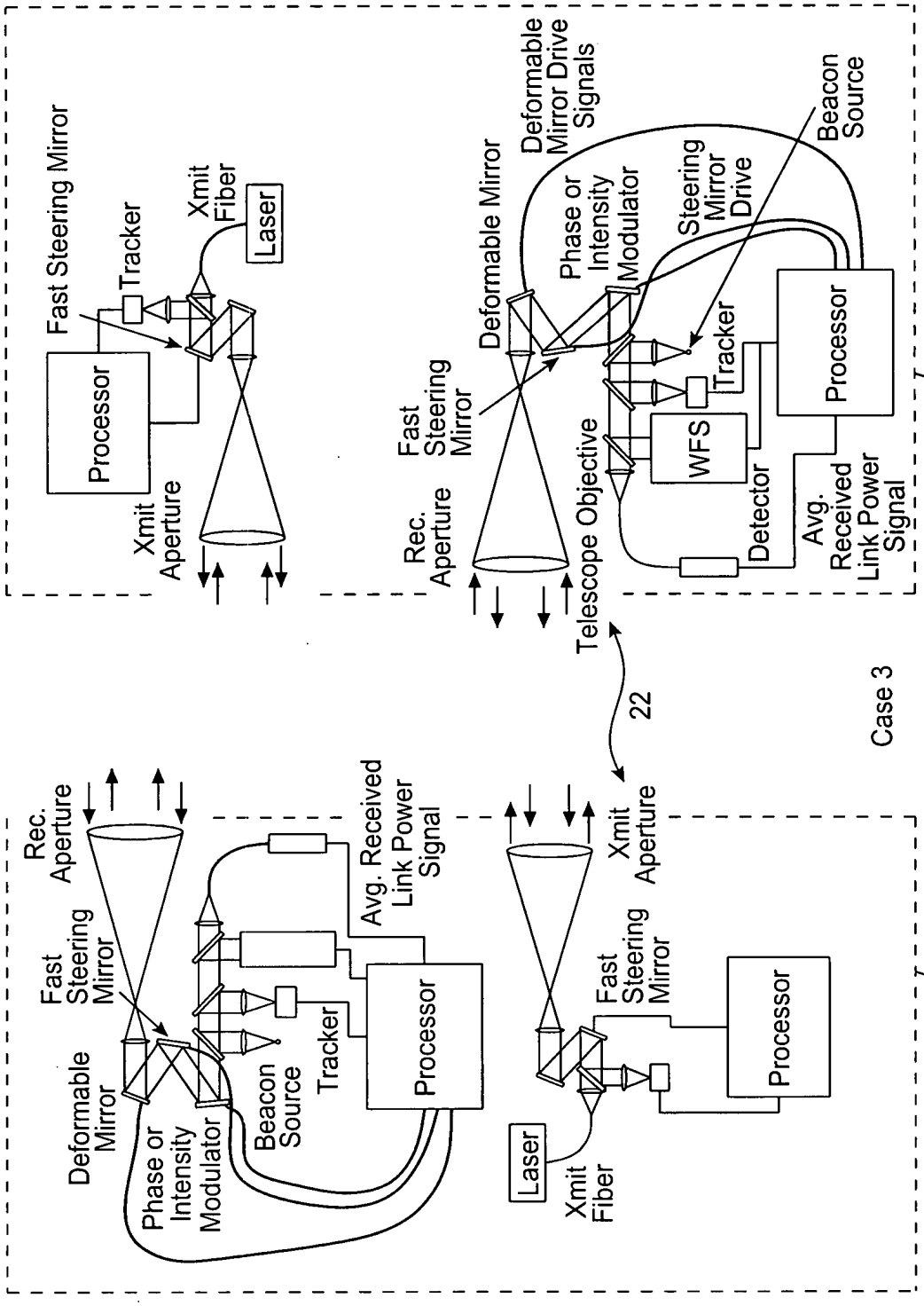

Fast Steering Mirror
Tracker
Xmit Fiber
Laser
Processor
Xmit Aperture
Deformable Mirror Drive Signals
Deformable Mirror
Phase or Intensity Modulator
Steering Mirror Drive
Beacon Source
Fast Steering Mirror
Tracker
WFS
Processor
Rec. Aperture
Detector
Avg. Received Link Power Signal
21B
Telescope Objective
22
Case 3
Rec. Aperture
Fast Steering Mirror
Deformable Mirror
Phase or Intensity Modulator
Beacon Source
Tracker
Processor
Avg. Received Link Power Signal
Xmit Aperture
Fast Steering Mirror
Processor
Laser
Xmit Fiber
21A
20

FIG. 8B

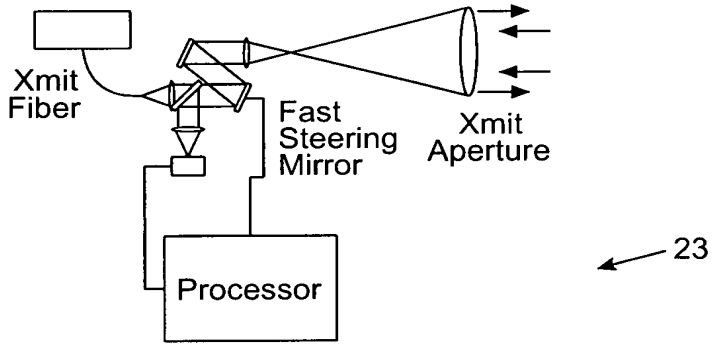

Xmit
Fiber
Fast
Steering
Mirror
Xmit
Aperture
Processor
23

FIG. 8C

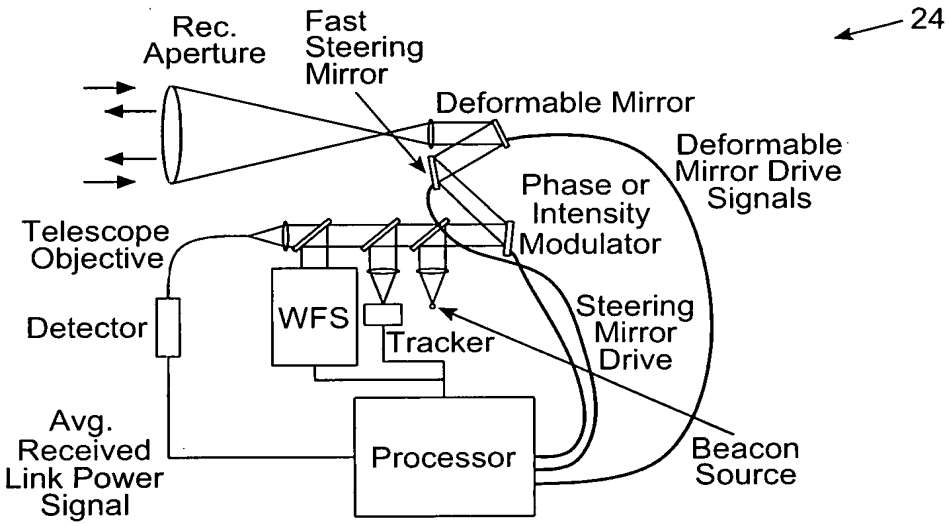
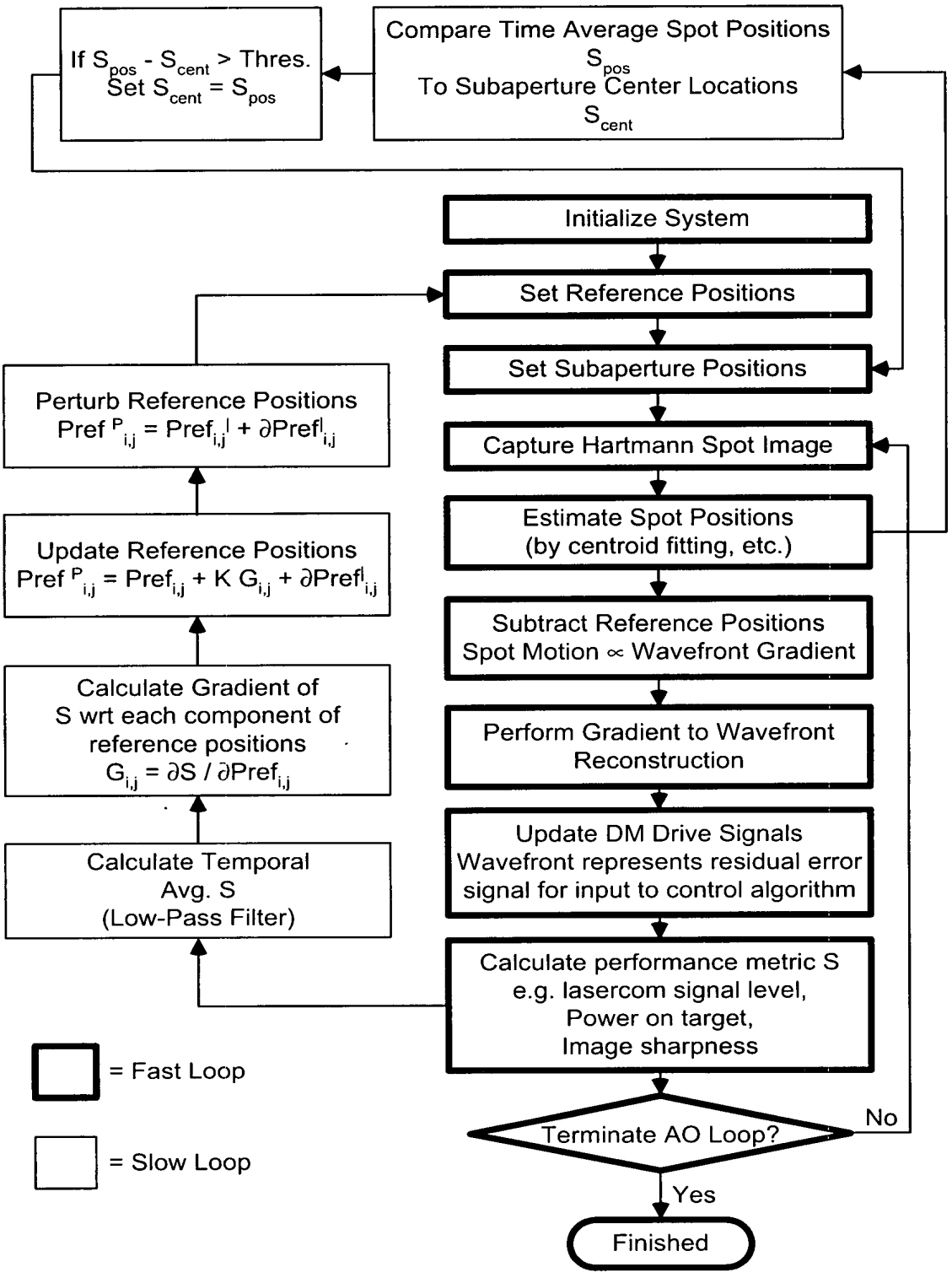
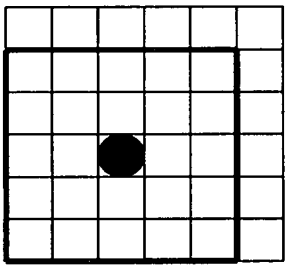

24
Rec.
Aperture
Fast
Steering
Mirror
Deformable Mirror
Deformable
Mirror Drive
Signals
Phase or
Intensity
Modulator
Telescope
Objective
Detector
WFS
Tracker
Steering
Mirror
Drive
Avg.
Received
Link Power
Signal
Processor
Beacon
Source

FIG. 8D



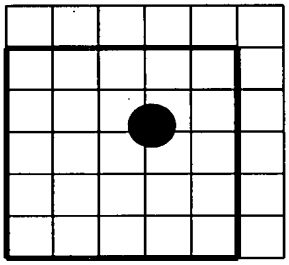
WF Control with Active Update of References

FIG. 8E



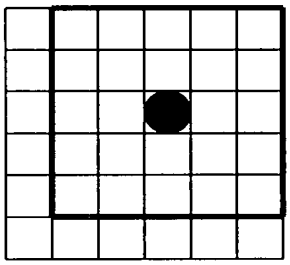
Spot near center of subaperture region

FIG. 8F1



Spot moving away from center of subaperture region

FIG. 8F2



When some threshold distance from center is crossed, redefine subaperture to re-center spot

FIG. 8F3

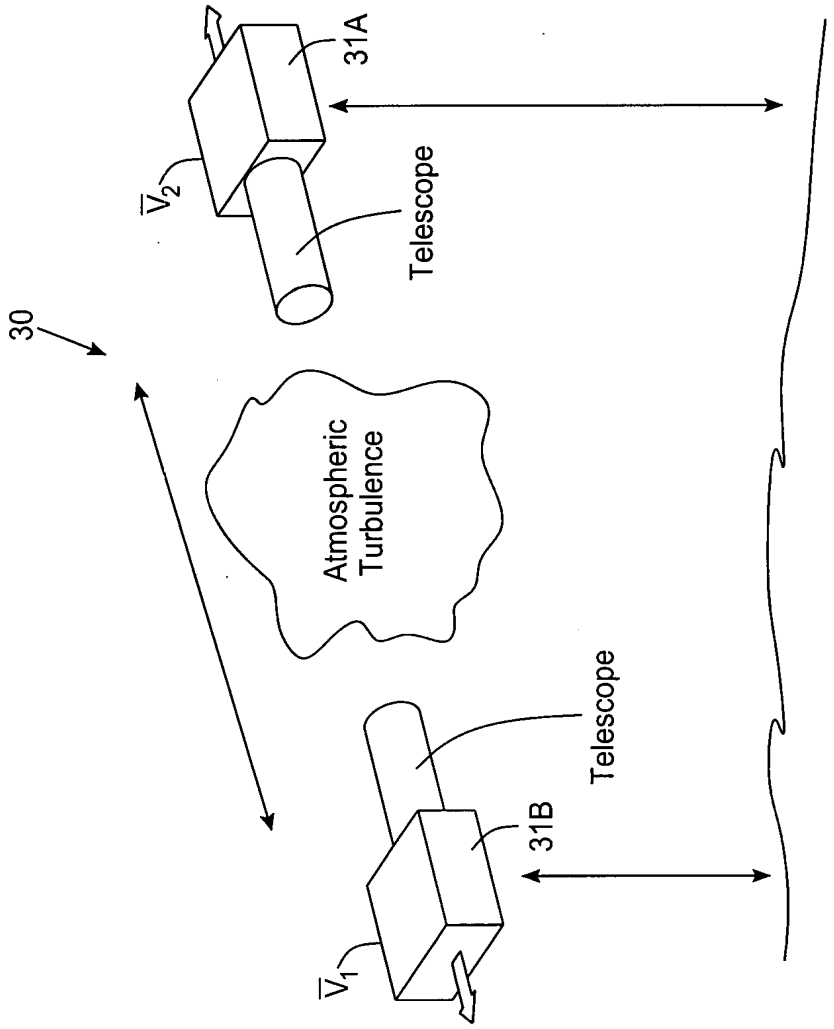

30
31A
Telescope
$\bar{V}_2$
Atmospheric Turbulence
Telescope
31B
$\bar{V}_1$

FIG. 9A

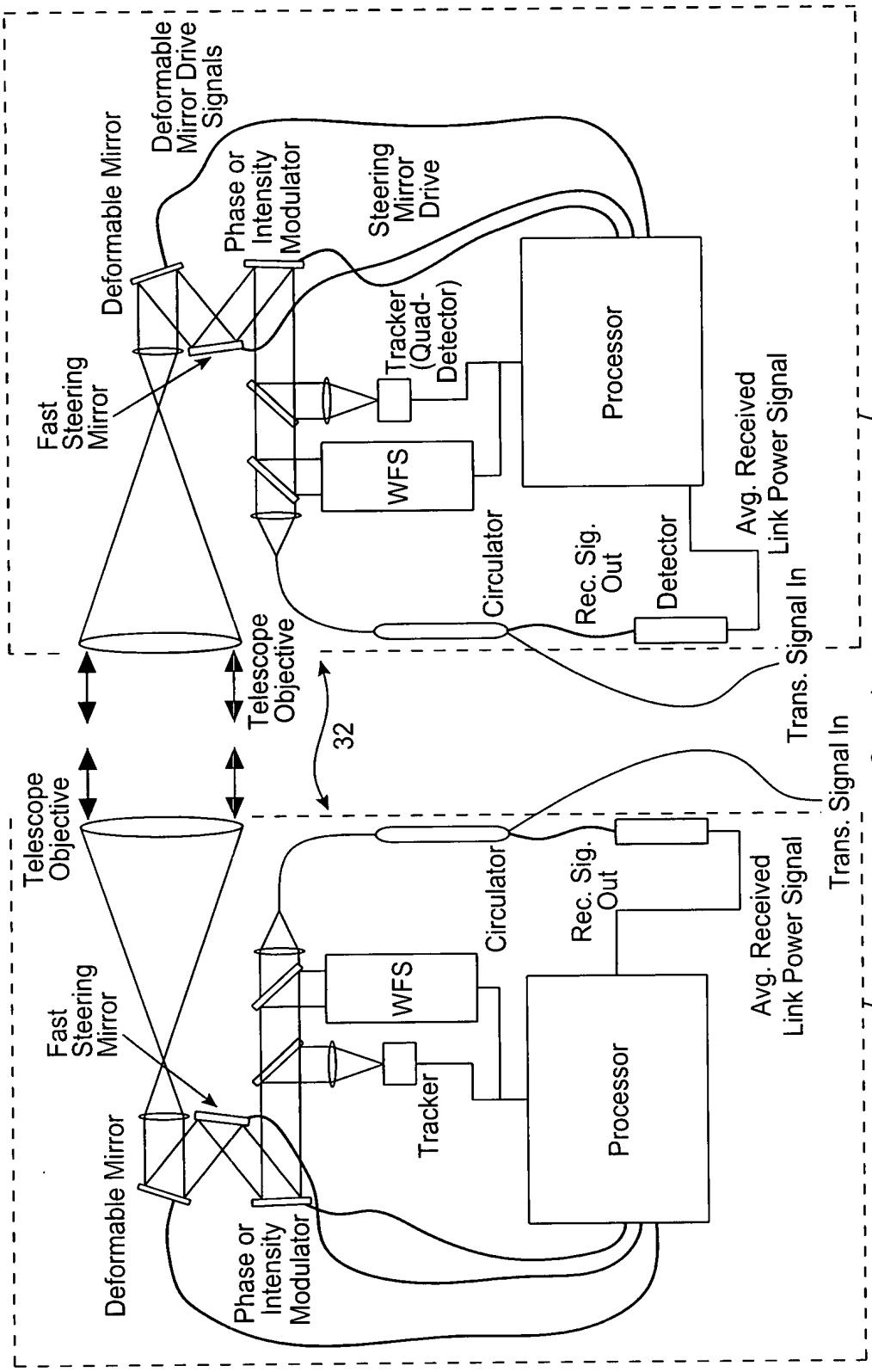

Deformable Mirror
Deformable Mirror Drive Signals
Phase or Intensity Modulator
Steering Mirror Drive
Fast Steering Mirror
Tracker (Quad-Detector)
Processor
WFS
Circulator
Rec. Sig. Out
Detector
Avg. Received Link Power Signal
Trans. Signal In
Telescope Objective
32
Case 4
31B
31A
"Retro-Reflective"

FIG. 9B

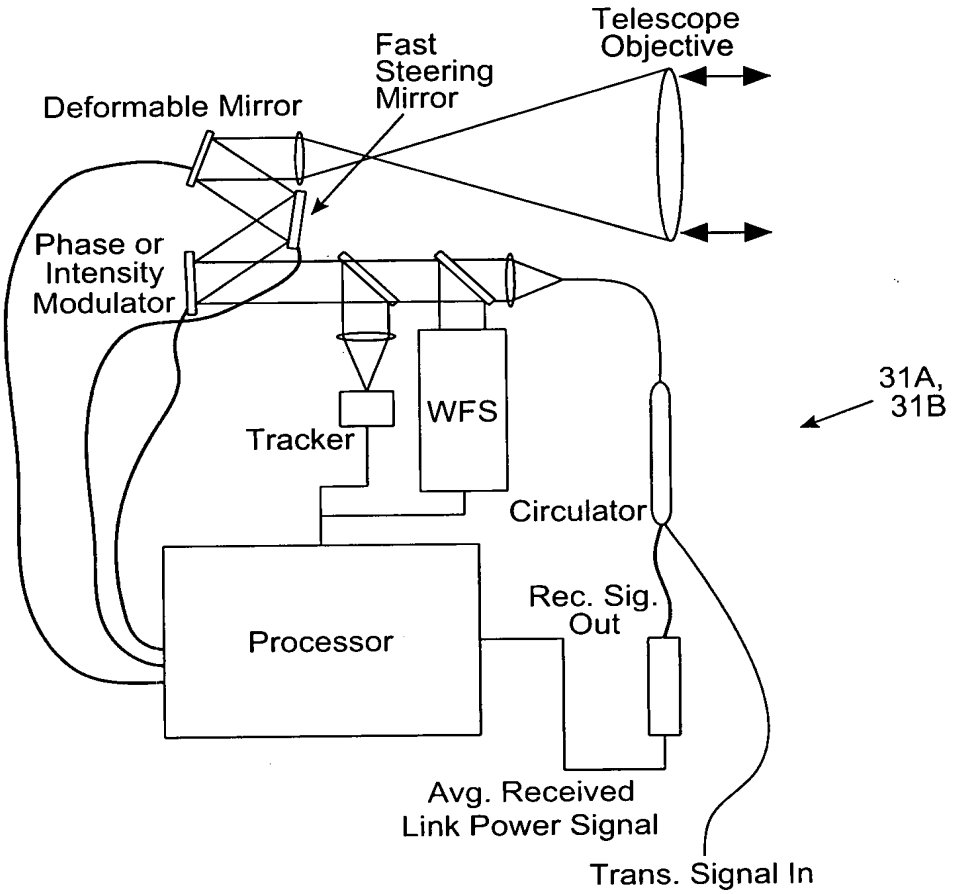

Telescope
Objective
Fast
Steering
Mirror
Deformable Mirror
Phase or
Intensity
Modulator
WFS
Tracker
31A,
31B
Circulator
Rec. Sig.
Out
Processor
Avg. Received
Link Power Signal
Trans. Signal In

FIG. 9C

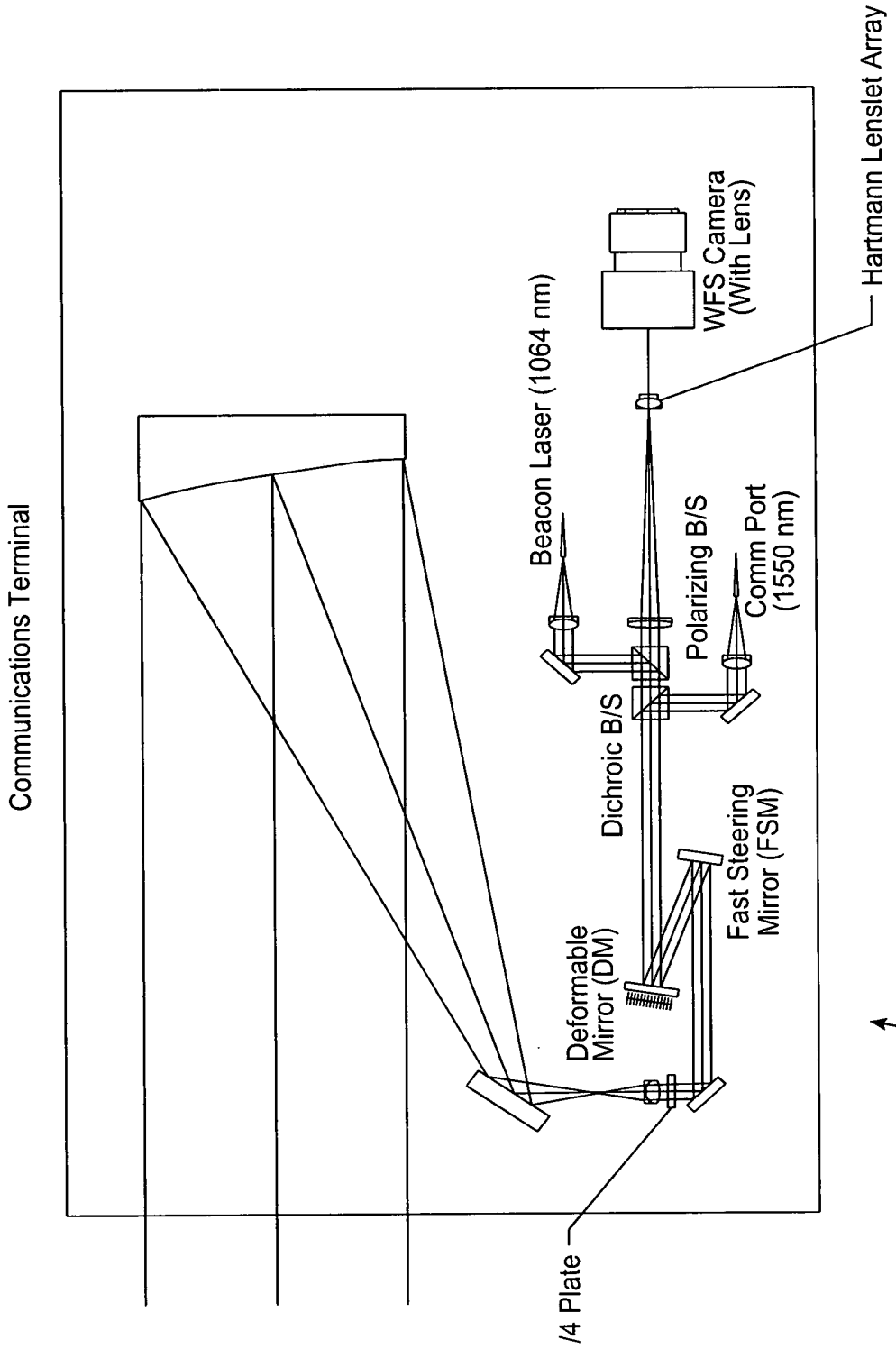

Communications Terminal
Beacon Laser (1064 nm)
WFS Camera (With Lens)
Hartmann Lenslet Array
Polarizing B/S
Comm Port (1550 nm)
Dichroic B/S
Fast Steering Mirror (FSM)
Deformable Mirror (DM)
/4 Plate
31A, 31B

FIG. 9D

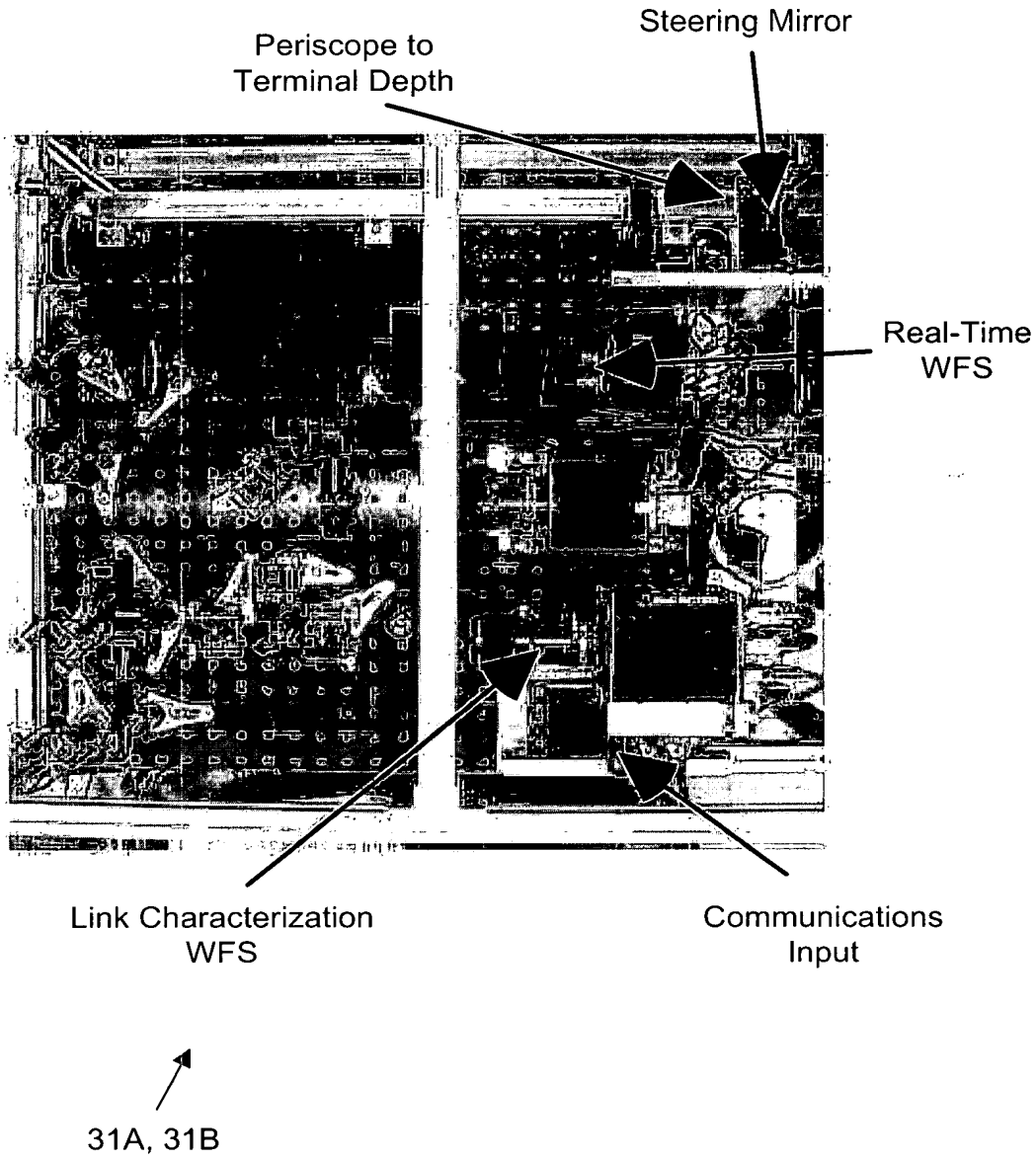
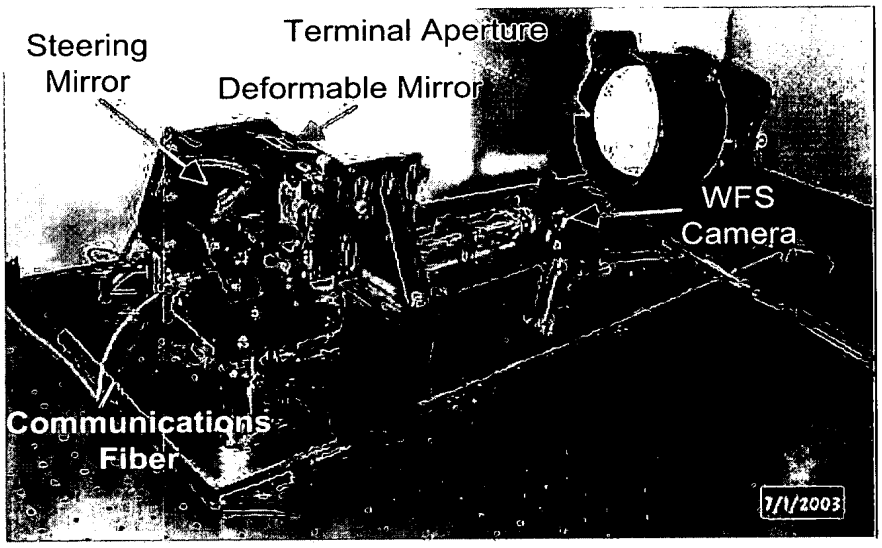

Periscope to
Terminal Depth
Steering Mirror
Real-Time
WFS
Link Characterization
WFS
Communications
Input
31A, 31B

FIG. 9E



Compact laser communications terminal with 15cm aperture. This terminal has both a fast steering mirror and deformable mirror for atmospheric compensation. This terminal is set up as either a transmitter or receiver, with a separate fiber port for a tracking and AO beacon laser source (hidden by the DM mount).

These are both laser comm. terminals with traditional adaptive optics. A terminal with fade prevention would look similar. Note that these use reflecting telescopes (the one on the top has an 8 inch Schmidt Cassegrain telescope on the other side of the optical breadboard. In the schematic drawings a refracting telescope is shown for simplicity. Either can be used in practice.

FIG. 9F

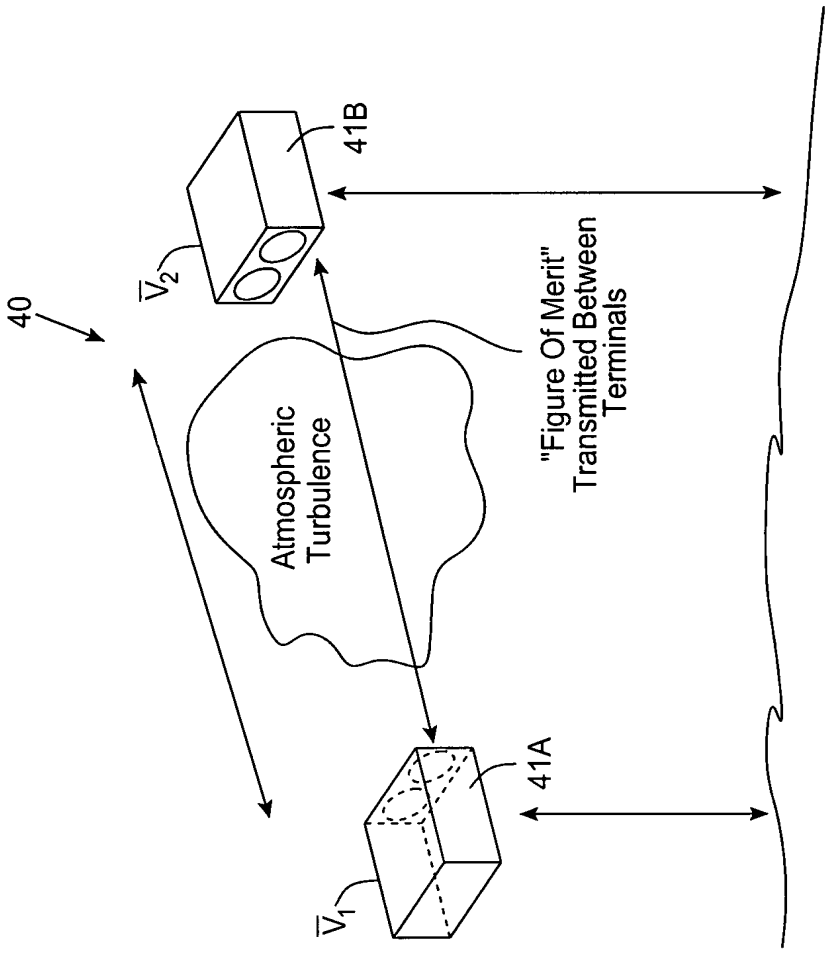

40
41B
41A
$\overline{V}_2$
$\overline{V}_1$
Atmospheric Turbulence
"Figure Of Merit" Transmitted Between Terminals

FIG. 10A

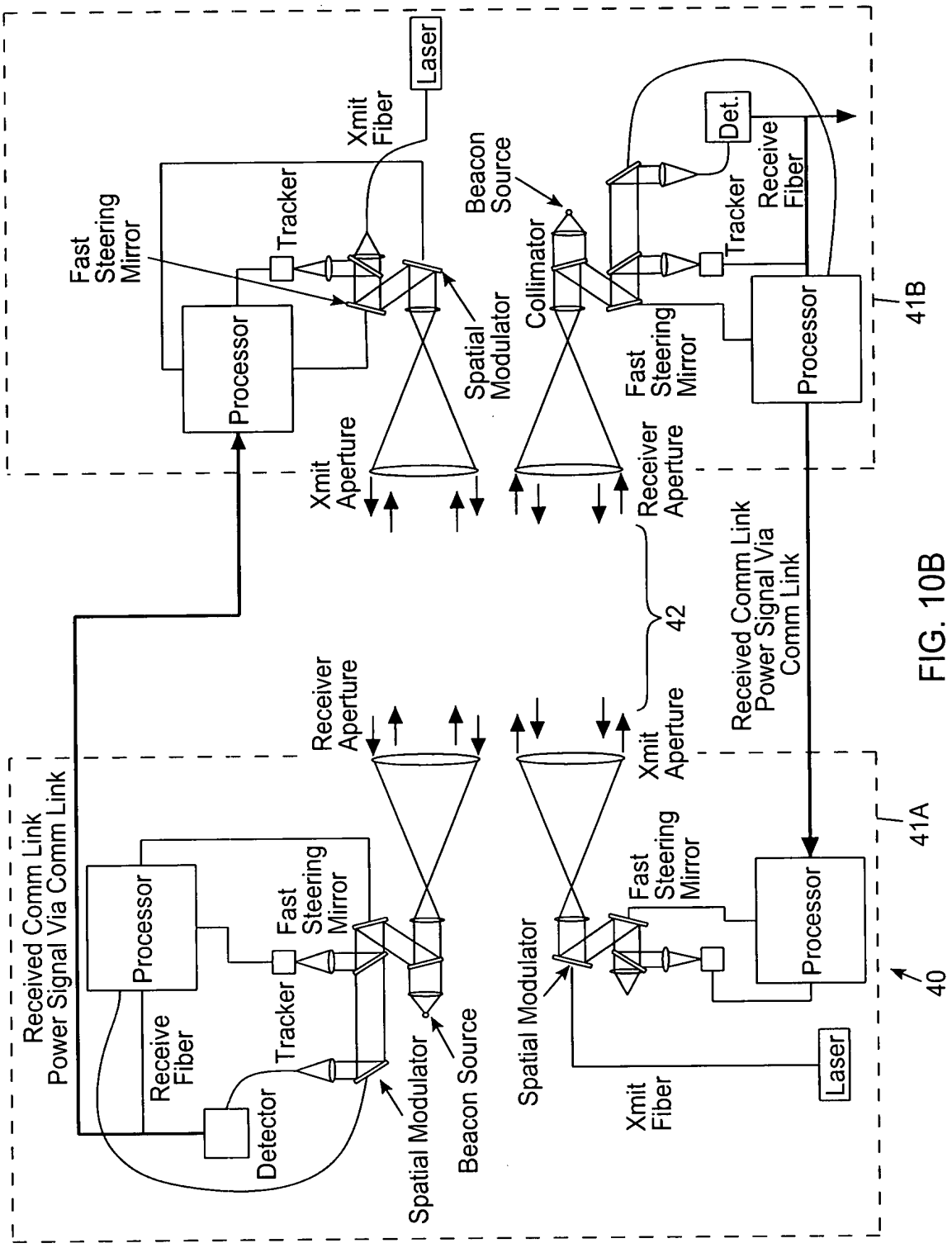

Laser
Xmit Fiber
Fast Steering Mirror
Tracker
Processor
Spatial Modulator
Beacon Source
Collimator
Det.
Receive Fiber
Xmit Aperture
Receiver Aperture
41B
42
41A
40
Received Comm Link Power Signal Via Comm Link
Receive Fiber
Detector

FIG. 10B